Appendix K
Facility Accidents

K.1 IMPACT ASSESSMENT METHODS FOR FACILITY ACCIDENTS

K.1.1 Introduction

The potential for facility accidents and the magnitude of their consequences are important factors for making reasonable choices among the various surplus plutonium disposition alternatives analyzed in the *Surplus Plutonium Disposition Environmental Impact Statement* (SPD EIS). Guidance on the implementation of 40 CFR 1502.22, as amended (EPA 1992), requires the evaluation of impacts that have a low frequency of occurrence but high consequences. Further, public comments received during the scoping process have clearly indicated the public's concern with facility safety and health risks and the need to address these concerns in the decisionmaking process.

For the No Action Alternative, potential accidents are defined in existing facility documentation, such as safety analysis reports (SARs), hazards assessment documents, National Environmental Policy Act (NEPA) documents, and probabilistic risk assessments (PRAs). The accidents include radiological and chemical accidents that have a low frequency of occurrence but high consequences, and a spectrum of other accidents that have a higher frequency of occurrence and lesser consequences. The data in these documents include accident scenarios, materials at risk, source terms (quantities of hazardous materials released to the environment), and consequences.

For each facility, a hazards analysis document identifying and estimating the effects of all major hazards that could affect the environment, workers, and the public would be issued in conjunction with the conceptual design package. Additional accident analyses for identified major hazards would be provided in a preliminary SAR issued during the period of definitive design (Title II) review. A final SAR would be prepared during the construction period and issued before testing began as final documented evidence that the new facility could be operated in a manner that did not pose any undue risk to the health and safety of workers and the public.

In determining the potential for facility accidents and the magnitude of their consequences, the SPD EIS considers two important concepts in the presentation of results: (1) risk and (2) uncertainties and conservatism.

K.1.1.1 Risk

One type of metric that can be obtained from the accident analysis results presented in the SPD EIS is accident risk. Risk is usually defined as the product of the consequences and estimated frequency of a given accident. Accident consequences may be presented in terms of dose (e.g., person-rem) or health effects (e.g., latent cancer fatalities [LCFs]). The accident frequency is the number of times the accident is expected to occur over a given period of time (e.g., per year). In general, the frequency of design basis and beyond-design-basis accidents is much lower than 1 per year, and therefore is approximately equal to the probability of the accident during 1 year. If an accident is expected to occur once every 1,000 years (i.e., a frequency of 1.0×10^{-3} per year) and the consequences of the accident is five LCFs, then the risk is $1.0\times10^{-3}\times5 = 5.0\times10^{-3}$ LCF per year.

A number of specific types of risk can be directly calculated from the Melcor Accident Consequence Code System (MACCS2) results reported in the SPD EIS (SNL 1997). One type of risk, average individual risk, is the product of the total consequences experienced by the population and the accident frequency, divided by the population.[1] For example, if an accident has a frequency of 1.0×10^{-3} per year, the consequence thereof is 5 LCFs, and the

[1] Population data for each facility considered in the SPD EIS can be found in Appendix J.

population in which the fatalities are experienced is 100,000, then the average individual risk is $1.0\times10^{-3} \times 5/100{,}000 = 5.0\times10^{-8}$ LCF per year. This metric is meaningful only when the mean value for consequence is used because risk itself is not a random parameter, even though it involves underlying randomness. It is noteworthy that the value of the average individual risk depends on the size of the area for which the population is defined. In general, the larger the area considered, the smaller the average individual risk for a given accident. The choice of an 80-km (50-mi) radius is common practice.

The average individual risk is a measure of the risk that an average individual (in this case within 80 km [50 mi] of the accident) experiences from specified accidents at the facility. This risk can be compared with other average individual risks, such as the risk of dying from a motor vehicle accident (about 1 in 80), the risk of death from fires (about 1 in 500), or the risk of accidental poisoning (about 1 in 1,000). These comparisons are not meant to imply that risks of an LCF caused by U.S. Department of Energy (DOE) operations are trivial, but only to show how they compare with other, more common risks. Radiological risks to the general public from DOE operations are considered to be involuntary risks as opposed to voluntary risks, such as operating a motor vehicle.

It is also possible to calculate population risk, which is the product of the total consequences experienced by the population and accident frequency. For example, if an accident has a frequency of 1.0×10^{-3} per year and the consequences of the accident is 5 LCFs, then the population risk is $1.0\times10^{-3}\times5 = 5.0\times10^{-3}$ LCF per year. Population risk is a measure of the expected number of consequences experienced by the population as a whole over the course of a year.

It would be inappropriate, however, to simply take the LCFs given the dose at 1,000 m (3,281 ft) or the LCFs given the dose at the site boundary and multiply them by the corresponding accident frequencies in an attempt to obtain the maximum individual risk to the noninvolved worker or the maximally exposed individual (MEI) member of the public. The reasons for this are discussed in the following paragraphs.

The distribution of centerline consequences from which the reported doses are obtained is constructed by modeling the accidental release many times using different weather conditions (i.e., windspeed, wind direction, stability class, and rainfall) each time. For each weather condition, the centerline consequences at 1,000 m (3,281 ft) and at the site boundary are calculated, and those values contribute to their respective distributions. Thus, given the accidental release, there is a 95 percent chance that the centerline consequences at 1,000 m (3,281 ft) and at the site boundary will fall below the reported 95th percentile consequences, and the expected consequences would be equal to the reported mean consequences. It is noteworthy, however, that the actual locations of the centerline consequences vary with wind direction, so the reported consequences are not associated with a specific point at 1,000 m (3,281 ft) or the site boundary. It is known only that the centerline consequences, wherever they might be, are characterized by the reported values.

A problem arises when these consequences are used to characterize individual risk. Although there is always some location that is exposed to the centerline consequences, no location is associated with the risk obtained by multiplying the centerline consequences by the accident frequency, because the direction of the plume centerline changes for each set of weather conditions. As a result, the risk to an individual at the location of maximum risk is likely to be much lower than the risk calculated by multiplying the centerline consequences by the accident frequency. In fact, because there are 16 sectors, and because doses decrease with lateral movement away from the centerline even within a sector, risk values generated in this way would tend to overstate the risk by a factor of as much as 100, and possibly more. The values are bounding, but have a potentially misleading degree of conservatism. Ultimately, MACCS2 is capable of calculating individual consequences at the point of maximum consequence (as reported in the SPD EIS), but it is not configured to calculate individual risk at the point of maximum risk.

K.1.1.2 Uncertainties and Conservatism

The analyses of accidents are based on calculations relevant to hypothetical sequences of events and models of their effects. The models provide estimates of the frequencies, source terms, pathways for dispersion, exposures, and the effects on human health and the environment that are as realistic as possible within the scope of the analysis. In many cases, a paucity of experience with the accidents postulated leads to uncertainty in the calculation of their consequences and frequencies. This fact has prompted the use of models or input values that yield conservative estimates of consequence and frequency. All alternatives have been evaluated using uniform methods and data, allowing for a fair comparison of all alternatives.

Although average individual and population risks can be calculated from the information in the SPD EIS, the equations for such calculations involve accident frequency, a parameter whose calculation is subject to considerable uncertainty. The uncertainty in estimates of the frequency of highly unlikely events can be several orders of magnitude. This is the reason accident frequencies are reported in the SPD EIS qualitatively, in terms of broad frequency bins, as opposed to numerically. Similarly, any metric that includes frequency as a factor will have at least as much, and generally more, uncertainty associated with it. Therefore, the consequence metrics have been preserved as the primary accident analysis results, and accident frequencies identified qualitatively, to provide a perspective on risk that does not imply an unjustified level of precision.

K.1.2 Safety Design Process

The proposed surplus plutonium disposition facilities would be designed to comply with current Federal, State, and local laws, DOE orders, and industrial codes and standards. This would result in a plant that is highly resistant to the effects of natural phenomena, including earthquake, flood, tornado, and high wind, as well as credible events as appropriate to the site, such as fire, explosions, and man-made threats.

The design process for the proposed facilities would comply with the requirements for safety analysis and evaluation in DOE Orders 430.1 and 5480.23. These orders require that the safety assessment be an integral part of the design process to ensure compliance with all DOE construction and operation safety criteria by the time the facilities are constructed and in operation.

The safety analysis process begins early in conceptual design with the identification of hazards that could produce unintended adverse safety consequences to workers or the public. As the design develops, failure modes and effects analyses (FMEAs) are performed to identify events capable of releasing hazardous material. The kinds of events considered include equipment failures, spills, human errors, fires, explosions, criticality, earthquakes, electrical storms, tornadoes, floods, and aircraft crashes. These postulated events become focal points for design changes or improvements to prevent unacceptable accidents. The analyses continue as the design progresses, the object being to assess the need for safety equipment and the performance of such equipment. Eventually, the safety analyses are formally documented in a SAR and, if appropriate, a PRA. The PRA documents the estimated frequency and consequences of a complete spectrum of accidents and helps to identify where design improvements could make meaningful safety improvements.

The first SAR, completed at the conclusion of conceptual design, includes identification of hazards and some limited assessment of a few enveloping design basis accidents. It includes deterministic safety analysis and FMEA of major systems. A comprehensive preliminary SAR, completed by the end of the preliminary design, provides a broad assessment of the range of design basis accident scenarios and the performance of equipment provided in the facility specifically for accident consequence mitigation. A limited PRA may be included in that analysis.

The SAR continues to be developed during detailed design. The safety review of the report and any supporting PRA are completed and safety issues resolved before the initiation of facility construction. Also, a final SAR is produced that includes documentation of safety-related design changes made during construction and the impact of those changes on the safety assessment. It also includes the results of any safety-related research and development that was performed to support the safety assessment of the facility. Approval of the final SAR is required before the facility is allowed to commence operation.

K.1.3 DOE Facility Accident Identification and Quantification

K.1.3.1 Background

Identification of accident scenarios for the proposed facilities is fairly straightforward. The proposed facilities are simple, and their processes have been used in other facilities for other purposes. From an accident identification and quantification perspective, therefore, these processes are well known and understood. Very few of the proposed activities would differ from activities at other facilities.

New facilities would likely be designed, constructed, and operated to provide an even lower accident risk than other facilities that have used these types of processes. The new facilities would benefit from lessons learned in the operation of similar processes. They would be designed to surpass existing plutonium facilities in the ability to reduce the frequency of accidents and to mitigate the consequences thereof.

A large experience base exists for the design of the proposed facilities and processes. Because the principal hazard to workers and the public from plutonium is the inhalation of very small particles, the safety management approach that has evolved is centered on control of those particles. The control approach is to perform all operations that could release airborne plutonium particles in a glovebox. The glovebox protects workers from inhalation of the particles and provides a convenient means for the collection of any particle that becomes airborne on filters. Air from the gloveboxes, operating areas, and buildings is exhausted through multiple stages of high-efficiency particulate air (HEPA) filters and monitored for radioactivity prior to release from the building. These exhaust systems are designed for effective performance even under the severe conditions of design basis accidents, such as major fires involving an entire process line.

While the new processes and facilities would be designed to reduce the risks of a wide range of possible accidents to a level deemed acceptable, some such risks would remain. As with all engineered structures—e.g., houses, bridges, dams—there is some level of earthquake or high wind the structure could not survive. While new plutonium facilities must be designed to very high standards—for instance, they must survive, with little plutonium release, a 1-in-10,000-year earthquake—an accident more severe than the design basis can always be postulated. Current DOE standards require that new facilities be designed to prevent to the extent possible, and then withstand, control, and mitigate, all credible process-related accidents. For safety analysis purposes, credible accidents are generally defined as accidents with frequencies greater than 1 in 1 million per year, including such natural-phenomena-induced accidents as earthquakes, high winds, and flooding. The accidents considered in the design, construction, and operation of these facilities are generally called design basis accidents.

In addition to the accident risks from the design basis accidents, the new facilities would face risks from beyond-design-basis accidents. For most plutonium facilities, the design basis includes all types of process-related accidents that have occurred in past operations: major spills, leaks, transfer errors, process-related fires, explosions, and nuclear criticalities. Certain natural-phenomena-initiated accidents also meet the DOE design basis criteria. While extremely unlikely, all new plutonium facilities, as essentially all manmade structures, could collapse under the influence of an earthquake. For most new plutonium facilities, the worst possible accident is a beyond-design-basis earthquake that results in partial or total collapse of the structure, spills, possibly fires, and loss of confinement of the plutonium powder. Also conceivable are such external events as the crash of a large aircraft onto the structure with an ensuing fuel-fed fire. At most locations away from major airports, however, the likelihood is less than 1 in 10 million per year. For some locations, such as Pantex, the frequency is higher, so aircraft crash–initiated accidents are a basic consideration.

The accident analysis reported in the SPD EIS is less detailed than a formal PRA or facility safety analysis because it addresses bounding accidents (accidents with low frequency of occurrence and high consequence) and a representative spectrum of possible operational accidents (accidents with high frequency of occurrence and low consequence). The technical approach for the selection of accidents is consistent with the DOE Office of NEPA Oversight's *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993), which recommends consideration of two major categories of accidents: design basis accidents and beyond-design-basis accidents.[2]

K.1.3.2 Identification of Accident Scenarios and Frequencies

A range of design basis and beyond-design-basis accident scenarios have been identified for each of the surplus plutonium disposition technologies (UC 1998a–h, 1999a–d). For each technology, the wide range of process-related accidents possible during construction and operation of the facility have been evaluated to ensure that their consequences are low or the frequency of occurrence, extremely low.

All of the analyzed accidents would involve a release of small, respirable plutonium particles or direct gamma and neutron radiation, and to a lesser extent, fission products from a nuclear criticality. Analyses of each proposed operation for accidents involving hazardous chemicals are reflected in the data reports supporting the SPD EIS. However, as the quantities of hazardous chemicals to be handled are small relative to those of many industrial facilities, no major chemical accidents were identified. The general categories of process-related accidents considered include:

- Drops or spills of materials within and outside the gloveboxes
- Fires involving process equipment or materials, and room or building fires
- Explosions initiated by the process equipment or materials or by conditions or events external to the process
- Nuclear criticalities

The analyses considered synergistic effects and determined that the only significant source of such effects would be a seismic event (i.e., a design basis seismic event or a seismically induced total collapse). The synergy would be due to the common-cause initiator (i.e., seismic ground motion). This was accounted for by summing population doses and LCFs for alternatives in which facilities would be located at the same site. MEI doses were not summed because an individual would only receive a summed dose if he or she were located along the line connecting the release points from two facilities and the wind were blowing along the same line at the time of the accident.

For each of these accident categories, a conservative preliminary assessment of consequence was made, and where consequences were significant, one or more bounding accident scenarios were postulated. The building confinement and fire suppression systems would be adequate to reduce the risks of most spills and minor fires. The systems would be designed to prevent, to the extent practicable, larger fires and explosions. Great efforts have always been made to prevent nuclear criticalities, which have the potential to kill workers in their immediate

[2] Some of the data reports supporting the SPD EIS use the terms "evaluation basis" and "beyond-evaluation-basis" to denote the two major categories of accidents. For clarity, the SPD EIS uses the terms "design basis" and "beyond-design-basis" throughout.

vicinity. In all cases, standard practice is expected to keep the frequency of accidental nuclear criticalities as low as possible.

The proposed surplus plutonium disposition facilities would be expected to meet or exceed the requirements of DOE Order 420.1, *Facility Safety,* and *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (DOE-STD-1020-94) (DOE 1994a), or the requirements of 10 CFR 70, *Domestic Licensing of Special Nuclear Material,* if the proposed facility were to be licensed by the U.S. Nuclear Regulatory Commission (NRC). Because the DOE and, if applicable, NRC design criteria require that new plutonium-processing buildings be of very robust, reinforced-concrete construction, very few events outside the building would have sufficient energy to threaten the building confinement. The principal concern would be the crash of a large commercial or military aircraft into the facility. Such an event, however, is highly unlikely. Only those crashes with a frequency greater than 10^{-7} per year are addressed in the SPD EIS.

Design basis and beyond-design-basis natural-phenomena-initiated accidents are also considered. Because of the robust nature of construction of new plutonium facilities, the only design basis natural-phenomena-initiated accidents with the potential to impact the facility interior are seismic events. Similarly, seismic events also bound the consequences and risks posed by beyond-design-basis natural phenomena.

The suite of generic accidents in the *Storage and Disposition PEIS* (DOE 1996a) was considered in the analysis of accidents for the SPD EIS. However, the more detailed design information in the surplus plutonium disposition data reports was the primary basis for the identification of accidents because it most accurately represents the expected facility configuration. The fire on the loading dock and the oxyacetylene explosion in a process cell were unsupported by this information, so were not included in the SPD EIS.

Accident frequencies are generally grouped into the bins of "anticipated," "unlikely," and "extremely unlikely," with estimated frequencies of greater than 10^{-2}, 10^{-2} to 10^{-4}, and 10^{-4} to 10^{-6} per year, respectively. The accidents evaluated represent a spectrum of accident frequencies and consequences ranging from low-frequency/high-consequence to high-frequency/low-consequence events. However, given the preliminary nature of the designs under consideration, it was not possible to assess quantitatively the frequency of occurrence of all the events addressed. The evaluation does not indicate the total risk of operating the facility, but does provide information on high-risk events that could be used to develop an accident risk ranking of the various alternatives.

K.1.3.3 Identification of Material at Risk

For each accident scenario, the material at risk—generally plutonium—was identified. Plutonium to be disposed of has a wide range of chemical and isotopic forms. The sources of plutonium vary among the various candidate facilities, and for specific facilities among various alternatives. Table K–1 presents the isotopic compositions that were used in the development of accident consequences in the SPD EIS. The vulnerability of material generally depends on the form of that material, the degree and robustness of containment, and the energetics of the potential accident scenario (UC 1998a:table 6-6; 1998c:tables 9-2 and A-7; 1998d:table B-1). For example, plutonium stored in strong, tight storage containers is not generally vulnerable to simple drops or spills, but may be vulnerable in a total collapse earthquake scenario.

Table K–1. Isotopic Composition of Plutonium Used in Accident Analysis (wt %)

Isotope	Pit Disassembly and MOX	Immobilization: Plutonium Conversion	Immobilization: First Stage, Hybrid Case	Immobilization: First Stage, 50-t Case
Plutonium 238	3.00×10^{-2}	0.0	0.0	2.0×10^{-2}
Plutonium 239	92.2	86.9	86.9	91.0
Plutonium 240	6.46	11.1	11.1	8.2
Plutonium 241	5.00×10^{-2}	1.5	1.5	5.80×10^{-1}
Plutonium 242	1.00×10^{-1}	5.0×10^{-1}	5.0×10^{-1}	2.50×10^{-1}
Americium 241	9.00×10^{-1}	1.0	1.0	9.4×10^{-1}

On an industrial scale, the quantities of hazardous chemicals are generally small. The occupational risks are generally limited to material handling and are managed under the required industrial hygiene program. No substantial hazardous chemical releases are expected.

K.1.3.4 Identification of Material Potentially Released to the Environment

The amount and particle size distribution of material aerosolized in an accident generally depends on the form of that material, the degree and robustness of containment, and the energetics of the potential accident scenario. Once the material is aerosolized, it must still travel through building confinement and filtration systems or bypass the systems before being released to the environment.

A standard DOE formula was used to estimate the source term for each accident at each of the proposed surplus plutonium facilities:

$$\text{Source Term} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF}$$

where:

MAR = material at risk (curies or grams)
DR = damage ratio
ARF = airborne release fraction
RF = respirable fraction[3]
LPF = leak path factor

The value of each of these factors depends on the details of the specific accident scenario postulated. ARF and RF were estimated according to reference material in *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE-HDBK-3010-94) (DOE 1994b). Conservative HEPA filter efficiencies of 0.999 and 0.99 were assumed, based on two stages of filtration, for a total LPF of 1.0×10^{-5}; however, actual efficiencies would likely be 0.999 and 0.998 or better. [Text deleted.]

No accident scenarios were identified that would result in a substantial release of plutonium or other radionuclides via liquid pathways.

[3] Respirable fractions are not applied in the assessment of doses based on noninhalation pathways, such as criticality.

K.1.4 Evaluation of Consequences of Accidents

K.1.4.1 Potential Receptors

For each potential accident, information is provided on accident consequences and frequencies to three types of receptors: (1) a noninvolved worker, (2) the maximally exposed member of the public, and (3) the offsite population. The first receptor, a noninvolved worker, is a hypothetical individual working on the site but not involved in the proposed activity. The worker is assumed to be downwind at a point 1,000 m (3,281 ft) from the accident. Although other distances closer to the accident could have been assumed, the calculations break down at distances of about 200 m (656 ft) or less due to limitations in modeling the effects of building wake and local terrain on dispersion of the released radioactive substances. A worker closer than 1,000 m (3,281 ft) to the accident would generally receive a higher dose; a worker farther away, a lower dose. At some sites where the distance from the accident to the nearest site boundary is less than 1,000 m (3,281 ft), the worker is assumed to be at the site boundary. The second receptor, a maximally exposed member of the public, is a hypothetical individual assumed to be downwind at the site boundary. Exposures received by this individual are intended to represent the highest doses to a member of the public. The third receptor, the offsite population, is all members of the public within 80 km (50 mi) of the accident location.

Consequences to workers directly involved in the processes under consideration are addressed generically, without attempt at a scenario-specific quantification of consequences. This approach to in-facility consequences was selected for two reasons. First, the uncertainties involved in quantifying accident consequences become overwhelming for most radiological accidents due to the high sensitivity of dose values to assumptions about the details of the release and the location and behavior of the impacted worker. Also, the dominant accident risks to the worker of facility operations are from standard industrial accidents, as opposed to bounding radiological accidents. The accident fatality risk for DOE has been reported as 2.7×10^{-5} per person per year (DOE 1999a). According to historical data on standard industrial accidents, the national average fatality risk from manufacturing operations is 3.5×10^{-5} per person per year (DOL 1997).

Consequences for potential receptors as a result of plume passage were determined without regard for emergency response measures, and thus are more conservative than would be expected if evacuation and sheltering were explicitly modeled. Instead, it is assumed that potential receptors are fully exposed in fixed positions for the duration of plume passage, thereby maximizing their exposure to the plume. As discussed in Appendix K.1.4.2, a conservative estimate of total risk was obtained by assuming that all released radionuclides contributed to the inhalation dose rather than being removed from the plume by surface deposition, which is a less significant contributor to overall risk and is controllable through interdiction.

K.1.4.2 Modeling of Dispersion of Releases to the Environment

The MACCS2 computer code (version 1.12) was used to estimate the consequences of accidents for the proposed facilities. A detailed description of the MACCS2 model is available in NUREG/CR-4691 (NRC 1990). Originally developed to model the radiological consequences of nuclear reactor accidents, this code has been used for the analysis of accidents for many EISs and other safety documentation, and is considered applicable to the analysis of accidents associated with the disposition of plutonium.

MACCS2 models the offsite consequences of an accident that releases a plume of radioactive materials into the atmosphere, specifically, the degree of dispersion versus distance as a function of historical wind direction, speed, and atmospheric conditions. Were such an accidental release to occur, the radioactive gases and aerosols in the plume would be transported by the prevailing wind and dispersed in the atmosphere, and the population would be exposed to radiation. MACCS2 generates the distribution of downwind doses at specified distances, as well as the distribution of population doses out to 80 km (50 mi).

As implemented, the MACCS2 model evaluates doses due to inhalation of aerosols, such as respirable plutonium, as well as exposure to the passing plume. This represents the major portion of the dose that a noninvolved worker or member of the public would receive as a result of a plutonium disposition facility accident. The longer-term effects of plutonium deposited on the ground and surface waters after the accident, including the resuspension and inhalation of plutonium and the ingestion of contaminated crops, were not modeled for the SPD EIS. These pathways have been studied and been found not to contribute as significantly to dosage as inhalation, and they are controllable through interdiction. Instead, the deposition velocity of the radioactive material was set to zero, so that material that might otherwise be deposited on surfaces remained airborne and available for inhalation. This adds a conservatism to inhalation doses that can become considerable at large distances (as much as two orders of magnitude at the 80-km [50-mi] limit). Thus, the method used in the SPD EIS is conservative compared with dose results that would be obtained if deposition and resuspension were taken into account.

Longer-term effects of fission products released in a nuclear criticality accident have been extensively studied. The principal concern is ingestion of iodine 131 via milk that becomes contaminated due to the ingestion of contaminated grains by milk cows. This pathway can be controlled if necessary. In terms of the effects of an accidental criticality, doses from this pathway are small.

The potential for tritium contamination of the Ogallala aquifer as a consequence of an accident at Pantex involving tritium was identified as a specific concern during the development of the SPD EIS. The assessment of consequences of accidental tritium releases in the SPD EIS is consistent with the method used in the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995a). Unlike plutonium, oxidized tritium (i.e., water vapor) is not significantly deposited on the ground for subsequent percolation into the local groundwater except under conditions of rain or dew. Pantex has a rather arid climate, so the chance of these weather conditions at the time of an accident is slight. Moreover, even if it were to happen as indicated in Section 4.6.1.2 of the *Final Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components* (DOE 1996b), actual movement of contaminated groundwater off the site would require about 10 to 20 years. In fact, current test data show that it could take as long as 50 or more years for a contaminant plume to move off the site. The half-life of tritium is 12 years; therefore, any hypothetical contamination deposited on the ground surface and carried into the groundwater regime would be reduced by a factor of roughly 2 to 16 by the time it moved off the site. Because of these considerations, health consequences of contamination of the Ogallala aquifer were not considered to be a significant contributor to health risks from a tritium release accident.

The region around the facility is divided by a polar-coordinate grid centered on the facility itself. The user specifies the number of radial divisions and their endpoint distances. The angular divisions used to define the spatial grid correspond to the 16 directions of the compass.

MACCS2 was applied in a probabilistic manner using a weather bin–sampling technique. Centerline doses, as a function of distance, were calculated for each of 1,460 meteorological sequence samples, resulting in a distribution of doses reflecting variations in weather conditions at the time of the postulated accidental release. The code outputs the conditional probability of exceeding a dose as a function of distance. The mean and 95th percentile consequences are reported in the SPD EIS. Doses higher than the 95th percentile values would be expected only 5 percent of the time.

MACCS2 cannot be used to calculate directly the distribution of maximum doses (resulting from meteorological variations) around irregular contours, such as a site boundary. As a result, analyses that use MACCS2 to calculate site boundary doses usually default to calculating doses at the distance corresponding to the shortest distance to the site boundary. In effect, the site boundary is treated as if it were circular, with a radius equal to the shortest distance from the facility to the actual site boundary. While this approximation is conservative with respect to dose (with the possible exception of doses from elevated plumes), it eliminates the use of some site-specific information, namely the site boundary location (other than the nearest point), wind direction, and any correlation between wind direction and other meteorological parameters. Because the primary purpose of the SPD EIS is to aid in decisions about facility locations, and because differences in dose values among the various options are largely a function of site-specific variations, a different approach was taken to more accurately characterize the potential for maximum doses at the site boundary.

For the SPD EIS, MACCS2 was used to generate intermediate results that could be further processed to obtain the distribution of doses around the site boundary, accounting for variations in site boundary distance as a function of direction. The specific instrument was the Type B result option of MACCS2, which renders the distribution of doses at a specified radial distance within a specified compass sector, given a release. Type B results were requested for the site boundary distance for each of the 16 compass sectors over which the meteorological data is defined. This resulted in 16 separate dose distributions; one for each specific location around the site boundary. The distribution of maximum doses around the site boundary was constructed by first summing the values of the Type B distributions for each dose value. The resulting distribution was then truncated for low dose values to the point where the remainder of the distribution was normalized. This produced the distribution of maximum doses around the site boundary, which is the distribution from which the mean and 95th percentile doses are reported.

Radiological consequences may vary somewhat as a result of variations in the duration of release. For longer releases, there is a greater chance of plume meander (i.e., variations in wind direction over the duration of release). MACCS2 models plume meander by increasing the lateral dispersion coefficient of the plume for longer release durations, thus lowering the dose. For perspective, doses from an homogenous, 1-hr release would be 30 percent lower than those of a 10-min release as a result of plume meander; doses from a 2-hr release, 46 percent lower. The other effect of longer release durations is involvement of a greater variety of meteorological conditions in a given release, which reduces the variance of the resulting dose distributions. This would tend to lower high-percentile doses, raise low-percentile doses, and have no effect on the mean dose.

For the SPD EIS accident analysis, a duration of 10 min was assumed for all releases. This is consistent with the accident phenomenology expected for all scenarios, with the possible exception of fire. Depending on the circumstances, the time between fire ignition and extinction may be considerably longer, particularly for the larger, beyond-design-basis fires. However, even in a fire of long duration, it is possible to release substantial fractions of the total radiological source term in fairly short periods, as the fire consumes areas of high MAR concentrations. The assumption of a 10-min release duration for fire is intended to generically account for this circumstance.

K.1.4.3 Modeling of Consequences of Releases to the Environment

The mean and 95th percentile consequences of accidental radiological releases, given variations in meteorological conditions at the time of the accident, are calculated as radiological doses in terms of rem. The mean consequences, or the expected consequences of the accident, are an appropriate statistic for use in risk estimates. The 95th percentile consequences represent bounding consequences of the accident; that is, if the accident were to occur and release the stated source term, there would be a 95 percent probability of lower than the stated consequences. This statistic is thus useful for characterizing the bounding consequence potential of the proposed activity under the stated accident condition. The consequences are also expressed as the additional potential or likelihood of death from cancer for the noninvolved worker and the maximally exposed member of the public, and the expected number of incremental LCFs among the exposed population.

The probability coefficients for determining the likelihood of fatal cancer, given a dose, are taken from the *1990 Recommendations of the International Commission on Radiological Protection* (ICRP 1991). For low doses or low dose rates, respective probability coefficients of 4.0×10^{-4} and 5.0×10^{-4} fatal cancers per rem are applied for workers and the general public.[4] For high doses received at a high rate, respective probability coefficients of 8.0×10^{-4} and 1.0×10^{-3} fatal cancers per rem are applied for noninvolved workers and the public. These higher probability coefficients apply where doses are above 20 rem and dose rates above 10 rem/hr.

K.1.5 Accident Scenarios for Surplus Plutonium Disposition Facilities

Bounding design basis and beyond-design-basis accident scenarios have been developed from accident scenarios presented in each of the surplus plutonium disposition data reports (UC 1998a–h, 1999a–d). These scenarios are discussed in detail, along with specific assumptions for each facility and site, in these documents.

K.1.5.1 Accident Scenario Consistency

In preparing the accident analysis for the SPD EIS, the primary objective was to ensure consistency between the data reports so that results of the analyses for the proposed surplus plutonium disposition alternatives could be compared on as equal a footing as possible. In spite of efforts by all parties, some inconsistencies exist between the data reports. This does not imply technical inaccuracy in any analysis; it merely reflects the uncertainties and reliance on convention that are inherent in accident analyses in general. In order to provide a consistent analytical basis, information in the data reports has been modified or augmented as described below.

Aircraft Crash. It was decided early in the process of developing accident scenarios that aircraft crash scenarios would not be provided in the data reports, but would be developed, as appropriate, directly for the SPD EIS.

Frequencies of an aircraft crash into each facility for each alternative were developed in accordance with DOE-STD-3014 (DOE 1996c). The frequency of crashes involving aircraft capable of penetrating the subject facility (assumed to be all aircraft except those in general aviation) would be below 1.0×10^{-7} per year for all facilities except those at Pantex. For facilities at Pantex, the frequency of impact would be 1.7×10^{-6} per year.

Of the variety of impact conditions accounted for in the above frequency values (e.g., impact angle, direction, lateral distance from building center, speed) only a fraction would have the potential to produce consequences comparable to those reported in the SPD EIS, while other impacts (grazing impacts, impacts into office areas, etc.) would not result in significant radiological impacts. [Text deleted.] Aircraft crashes at Pantex with the potential for significant consequences could occur more frequently than 1.0×10^{-7} per year, so these scenarios were analyzed further.

For the facilities at Pantex, the potential for an aircraft crash into vaults containing large quantities of plutonium powder was examined in relation to the potential for a crash into the facility as a whole. For the pit conversion and mixed oxide (MOX) facilities, the footprint of the vault would be considerably less than one-tenth that of the facility as a whole, indicating that vault impact frequencies would be on the order of, and perhaps less than, one-tenth the facility impact frequencies. Moreover, fewer types of aircraft would have the potential to penetrate the vault due to the robustness of the reinforced-concrete vault structures and their location in the basements of the facilities. Inside the vault, the storage containers would provide additional protection against the release of material. The protection provided by the vault structure and the storage containers can be regarded as conducive to a further reduction in the frequency of aircraft crashes into vault areas.

In response to public concern over the risk of an aircraft crash at Pantex, and consistent with a Memorandum of Understanding between the DOE Amarillo Area Office and the Federal Aviation Administration (FAA), an

[4] Probability coefficients for the likelihood of nonfatal cancer are 8.0×10^{-5} for adult workers and 1.0×10^{-4} for the public. The probability coefficients for severe hereditary effects are 8.0×10^{-5} for adult workers and 1.3×10^{-4} for the public.

Overflight Working Group was established. This working group provided a number of recommendations for reducing the risk of an aircraft crash into any facility at Pantex. DOE supplemented the Memorandum of Understanding with an Interagency Agreement with the FAA. These actions resulted in the following recommendations:

- Modifying the vectoring of approaching aircraft to preclude extended flying over plant boundaries and reducing the number of aircraft turning on final approach over the plant

- Modifying holding patterns so that they are away from the plant

- Developing a new global positioning satellite (GPS), nonprecision approach to runway 22

- Replacing the backcourse localizer approach to runway 22 with an offset localizer approach

- Upgrading the lighting system for the approach to runway 4

- Establishing a hotline between the FAA and DOE

- Establishing new very high frequency omnidirection radio tactical (VORTAC) air navigation device locations

- Installing a GPS ground differential station, and commissioning a new GPS precision approach to runway 22

As of this date, all the recommendations except the last two have been implemented. The recommendation to install a precision approach is on hold until the FAA develops the standards for the augmentation system. While these changes cannot be quantitatively reflected in the frequency of aircraft crash as calculated by DOE-STD-3014, the improvements have been acknowledged as representing a reduction in the exposure of Pantex to aircraft, which translates to a reduction in the aircraft crash frequency at that site.

As a result of these considerations, it was qualitatively estimated that the overall scenario frequency of an aircraft crash into a plutonium powder vault associated with either the pit conversion or MOX facility was below the threshold frequency of 1.0×10^{-7} per year. Additionally, it was qualitatively estimated that in light of these considerations, the overall frequency of aircraft impact into the pit conversion or MOX facility at Pantex was below 1×10^{-6} per year, or "beyond extremely unlikely." The development of consequences of an aircraft crash was therefore refocused on the MAR that could be in process areas at the time of the crash. To develop representative consequences, it was assumed that the aircraft impact would involve the process area containing the largest amount of material in the most dispersable form. For the MOX facility, the impact was assumed to involve the unloading vessel and hopper storage, powder-blending process, and MOX powder storage areas. These processes would contain the bulk of process plutonium in powder form. The total quantity of plutonium in powder form would be 1.8×10^{5} g (6.3×10^{3} oz) (UC 1998d:table B-13), assuming that one-third of the plutonium in MOX powder storage was in powder form, one-third in green pellet form, and one-third in the form of sintered pellets. However, given the potentially high-energy densities associated with an aircraft crash, it was assumed that the green pellets would be equally vulnerable to release as powder, for a total effective powder quantity of 3.5×10^{5} g (1.2×10^{4} oz). For the pit conversion facility, the impact was assumed to involve the bisector, blending, canning, nondestructive analysis, and temporary storage areas, for a total of 6.0×10^{4} g (2.1×10^{3} oz) (UC 1998a:table 7-3) of plutonium in powder form.

The initial effect of the impact would be to disperse the material in a manner consistent with DOE-HDBK-3010-94 values for debris impact in powder. For this phenomenon, DOE-HDBK-3010-94 recommends bounding ARF and RF values of 1.0×10^{-2} and 0.2 (DOE 1994a:4-10), respectively, resulting in an initial source term of 117 g (4.1 oz) for the pit conversion facility and 690 g (24 oz) for the MOX facility. An aircraft crash could also induce a fire capable of entraining additional material in a lofted plume. The ARF and RF values for thermal stress, 6.0×10^{-3} and 1.0×10^{-2} (DOE 1994a:4-7), respectively, would result in a 3 percent increase in the source term. This additional source term should not contribute significantly to the noninvolved worker dose or the MEI dose, given the trajectory of the plume. However, it would contribute to the population dose. For simplicity, the source term was included in the ground-level release, yielding a total plutonium release of 124 g (4.4 oz) for the pit conversion facility and 710 g (25 oz) for the MOX facility.

The same source terms would result from postulated aircraft crashes into the pit conversion and MOX facilities regardless of their location. As discussed above, inclusion of the consequence analysis for Pantex, but not for other sites such as SRS, was solely due to differences in accident frequency.

Criticality. All of the data reports provide technically defensible information on criticality, but the analytical assumptions vary among the reports. To assess the significance of the variations, MACCS2 runs were performed for each criticality source term. The resulting doses varied by a factor of about 15 for all criticalities except the natural phenomena hazard (NPH) vault criticality in the immobilization data report. Doses from this criticality were roughly 100 times larger than any other doses and were dominated by aerosolized plutonium from the vault.

For the SPD EIS, it was decided to discard the NPH vault criticality on the grounds that it is, at most, an improbable event that is conditional on the occurrence of a beyond-design-basis earthquake and does not represent the potential consequences of an isolated criticality. Beyond-design-basis earthquakes have been addressed via a total collapse scenario in all data reports, and the additional assumption of a criticality occurring in addition to the total collapse does not significantly increase doses beyond those resulting from the collapse itself.

Of the remaining criticalities, the criticality in the rotary splitter tumbler in the glass immobilization data report produced the highest doses, dominated by fission products as opposed to plutonium. The source term for this criticality is based on a fission yield from 1.0×10^{19} fissions in an oxide powder.

For the SPD EIS, it was decided to use this source term for criticality for all facilities, because all facilities would handle oxide powder in quantities sufficient for criticality. For the aqueous plutonium-polishing process at the MOX facility, a solution criticality of 10^{19} fissions was also postulated, which bounds the powder criticality due to the greater release potential of fission products from solution. The estimated frequency of extremely unlikely (i.e., 10^{-6} to 10^{-4} per year) reported in the immobilization data report was also used because it is the bounding estimate.

The criticality source term provided in the immobilization data report neglects some very short-lived isotopes that would be expected in a criticality, namely bromine 85, iodine 136, krypton 89 and 90, and xenon 137. Since the half-lives of these isotopes are all less than 4 min, they do not have a significant direct impact on radiological consequences. However, the daughters of some of the isotopes are themselves radioactive; in particular, krypton 89 decays to rubidium 89, which has a half-life of 15 min. The significance of the daughters for overall consequences has been assessed for Pantex, which is considered bounding because Pantex has the highest windspeeds and tends to carry the daughters the farthest for a given level of decay. As expected, the increase in dose is greatest for the noninvolved worker; approximately 25 percent higher for both the mean and 95th percentile. The dose increase decreases to 3 and 13 percent, respectively, for the mean and 95th percentile doses to the population within 80 km (50 mi). Dose increases at other sites are expected to be lower than corresponding increases at Pantex. Because these increases are small considering the great uncertainty inherent in the estimate of the total number of fissions, the source term in the immobilization data report remains a conservative estimate of the potential release from a criticality accident, and no modification of the source term has been made.

Design Basis Earthquake. Each data report presents an analysis of the design basis earthquake. The immobilization and MOX data reports provide source terms for that earthquake, while the pit conversion data reports indicate no release as a result of a design basis earthquake because the facility would be designed to withstand the event.

For the SPD EIS, a nonzero source term for pit conversion was generated by applying a building ventilation LPF of 1.0×10^{-5}, accounting for a HEPA filtered release, to the beyond-design-basis earthquake source term. It is recognized that this is a conservative procedure, in that the beyond-design-basis earthquake would release more material into the air within the building than a design basis earthquake. The combined ARF×RF for powder under beyond-design-basis earthquake conditions has been assessed as three times that for design basis earthquake conditions, and the total amount of vulnerable material may be somewhat greater. (For perspective, it resulted in a ratio of design basis earthquake to beyond-design-basis earthquake source term values that is somewhat higher than the corresponding ratio for MOX fuel fabrication, but lower than for plutonium conversion and immobilization.)

Beyond-Design-Basis Earthquake. All of the proposed operations would be in either existing or new facilities that would be expected to meet or exceed the requirements of DOE O 420.1 (DOE 1995b) and DOE-STD-1020-94 for reducing the risks associated with natural phenomena hazards. The proposed facilities would be characterized as Performance Category 3 facilities. Such facilities would have to be designed or evaluated for a design basis earthquake with a mean annual exceedance probability of 5×10^{-4}, corresponding to a return period of 2,000 years. For sites such as Lawrence Livermore National Laboratory (LLNL), which are near tectonic plate boundaries, the requirements would include a mean annual seismic hazard exceedance probability of 1.0×10^{-3}, or a return period of 1,000 years.

The numerical seismic design requirements detailed in DOE-STD-1020-94 are structured such that there is assurance that specific performance goals are met. For plutonium facilities (Performance Category 3), the performance goal is that occupant safety, continued operation, and hazard confinement would be ensured for earthquakes with an annual probability exceeding approximately 1×10^{-4}. There is sufficient conservatism in the design of buildings and the structures, systems, and components important to safety that these goals should be met given that they are designed against earthquakes with an estimated mean annual probability of 5×10^{-4}.

[Text deleted.]

By contrast, nonnuclear structures at these sites and the surrounding community would be constructed to the standards of the Uniform Building Code for that region. These peak acceleration values are 50 to 82 percent of the peak acceleration design requirements for plutonium facilities in the same area and correspond approximately to DOE Performance Category 1 facilities with 500-year return intervals. During major earthquakes, structures built to these Uniform Building Code requirements would be expected to suffer significantly more damage than reinforced-concrete structures designed for plutonium operations.

At sites far from tectonic plate boundaries, deterministic techniques such as those used by NRC in evaluating safe-shutdown earthquakes for the siting of nuclear reactors have also been used to determine the maximum seismic ground motion requirements for facility designs. These techniques involve estimating the ground acceleration at the proposed facility either by assuming the largest historical earthquake within the tectonic province or by assessing the maximum earthquake potential of the appropriate tectonic structure or capable fault closest to the facility. For NRC-licensed reactors, this technique resulted in safe-shutdown earthquakes with estimated return periods in the 1,000- to 100,000-year range (DOE 1994a:C-17).

All the existing facilities under consideration in the SPD EIS have had seismic evaluations demonstrating that they meet the seismic evaluation requirements for the design basis earthquake. Some facilities, such as

Building 332 at LLNL under consideration for preparation of the lead test assemblies, have had extensive evaluations of the ability of the structures, systems, and components important to safety to survive a range of seismic loadings. Evaluations reported in the *Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (DOE 1992) indicate that Building 332 would survive a postulated 0.8g earthquake and retain those features essential for the safe containment of radioactive materials. The estimated return interval for this level of ground accelerations is about 10,000 years. The facility was also examined for damage due to a 0.9g earthquake and found to be survivable (DOE 1992:app. D.5.2.1), albeit with some potential for loss of confinement due to equipment damage in safety systems (DOE 1992:table I-14).

The magnitude of potential earthquakes with return periods greater than 10,000 years is highly uncertain. For purposes of the SPD EIS, it was assumed that at all the candidate sites, earthquakes with return periods in the 100,000- to 10-million-year range might result in sufficient ground motion to cause major damage to even a modern, well-engineered and well-constructed plutonium facility. Therefore, in the absence of convincing evidence otherwise, a total collapse of the plutonium facilities was assumed to be scientifically credible and within the rule of reason for return intervals in this range.

Each data report presents an analysis of total collapse. The immobilization and MOX data reports are fairly consistent in their use of damage estimates and release fractions. They assume that material in storage containers in vault storage would be adequately protected from the scenario energetics, for a damage ratio of zero in the vault. They also assume powder ARF and RF values of 1.0×10^{-3} and 0.3 (UC 1998c:tables 8-14 and 8-15; 1998d:169), respectively. The pit conversion data reports assume a damage ratio of 50 percent for material held in storage containers, applies cumulative ARF and RF values of 2.7×10^{-3} to powder subject to seismic vibration, free-fall spill, and turbulent air currents; and also presents a resuspension source term (UC 1998a:79–81).

For the SPD EIS, the pit conversion source term was modified by adjusting the damage ratio in the vault from 0.5 to 0 based on the corresponding analyses in the immobilization and MOX data reports, and adjusting the ARF and RF values for powder to 1.0×10^{-3} and 0.3, respectively. The assumption of vault survival in the beyond-design-basis earthquake was based on the fact that the vaults would be designed with significantly more robustness than the balance of the proposed facilities. The requirements for the additional robustness of the vault derive from the desire for increased protection of vault contents against external events such as aircraft crash or proliferation concerns, as well as increased earthquake survivability. It is expected that the vaults would survive the most likely seismic events of sufficient magnitude to collapse the processing areas of the proposed facilities. While there may be even more intense seismic events capable of compromising the protection afforded by the vaults, such events are expected to be beyond extremely unlikely.

The value of 2.7×10^{-3}, used in the pit conversion data report, is based on seismic-induced collapse of large structures into loose bulk powder; this assumption is considered unnecessarily conservative given the expectation of containered storage for the majority of the powder inventory at any given time. The resuspension source term was kept (and was not applied to either immobilization or MOX). Although worth noting, this difference between the data reports is not considered particularly significant, for the resuspension source term constitutes only 30 percent of the total.

The frequency for all beyond-design-basis earthquakes for all facilities is reported in the SPD EIS as extremely unlikely to beyond extremely unlikely (the pit conversion facility data report estimated a frequency of less than 1×10^{-6} per year.) They are reported as such because the uncertainties inherent in associating damage levels with earthquake frequencies become overwhelming below frequencies of about 1.0×10^{-5} per year.

Filtration Efficiency. The immobilization and MOX data reports use a building filtration efficiency of 1.0×10^{-5} for particulate releases (UC 1998c:8-3; 1998d:tables B-18–B-20). The pit conversion data report uses a building filtration efficiency of 2.0×10^{-6} (UC 1998a:73). For consistency, the pit conversion source terms have been adjusted to reflect an LPF of 1.0×10^{-5}. This is reasonable because it is expected that the ventilation efficiencies of all HEPA-filtered buildings would be essentially the same.

Beyond-Design-Basis Fire. The MOX data report presents an analysis of a beyond-design-basis fire whose basis in terms of scenario definition was from the *Data Report for Plutonium Conversion Facility* (Smith, Wilkey, and Siebe 1996), which was produced for the *Storage and Disposition PEIS* (DOE 1996a). Neither the pit conversion nor the immobilization data reports contain analyses of a beyond-design-basis fire.

For the SPD EIS, beyond-design-basis fires were developed for pit conversion and immobilization by replacing the building filtration LPF with an LPF of 1.4 percent, in accordance with the beyond-design-basis scenario definition presented in the *Data Report for Plutonium Conversion Facility* (Smith, Wilkey, and Siebe 1996) and adapted for the MOX fuel fabrication analysis. (For perspective, it resulted in a ratio of design basis fire to beyond-design-basis fire source term values that are within a factor of 2 of the corresponding ratio for MOX fuel fabrication.)

It is understood that the LPF of 1.4 percent is based on a facility-specific analysis of the Plutonium Finishing Building (PF–4) in Technical Area 55 at LANL, and that an analysis of other facilities using the same phenomenological assumptions might yield somewhat different results. However, for the purpose of this analysis, and considering the degree of similarity expected between facilities as a result of required plutonium-handling practices, this value was used generically in the assessment of beyond-design-basis fire.

K.1.5.2 Facility Accident Scenarios

K.1.5.2.1 Pit Conversion Facility

A wide range of potential accident scenarios were considered for the pit conversion facility. These scenarios are considered in detail in the pit conversion facility data reports (UC 1998a, 1998c, 1998e, 1998f). The analysis assumes that the pit conversion facility is located in a new or upgraded existing building designed to withstand design basis natural phenomena hazards such as earthquakes, winds, tornadoes, and floods such that no unfiltered releases would be expected. Also, no site-specific accidents conducive to releases are identified. Therefore, the potential accident scenarios apply to all four candidate sites.

Analysis of the proposed process operations for the pit conversion facility identified the following broad categories of accidents: aircraft crash, criticality, design basis earthquake, beyond-design-basis earthquake, explosion, fire, leaks or spills, and tritium release. Basic characteristics of each of these postulated accidents are described below. Additional discussion of scenario development based on consistency concerns can be found in Appendix K.1.5.1.

Aircraft Crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficient to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative but would be expected to exceed those from the beyond-design-basis earthquake. At all sites except Pantex, the frequency of such a crash is below 10^{-7} per year.

Criticality. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It is assumed that human error results in multiple failures leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year. A bounding source term resulting from 10^{19} fissions is assumed.

Design Basis Earthquake. The principal design basis natural phenomena event that could release material to the environment is the design basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system should continue to function, the vibratory motion would be expected to resuspend loose plutonium powder within gloveboxes and cause some minor spills. These would be picked up by the ventilation system and filtered by the HEPA filters before release from the building. Although highly uncertain, the source term should be much lower than that postulated for the beyond-design-basis earthquake. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 3.9×10^{-4} g (1.4×10^{-5} oz) is postulated. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-2} per year.

Beyond-Design-Basis Earthquake. The postulated beyond-design-basis earthquake is assumed to be of sufficient magnitude to cause total collapse of the process equipment, building walls, roof, and floors, and loss of the containment function of the building. The material in the building is assumed to be driven airborne by the seismic vibrations, free-fall during the collapse, and impact. Molten metal in furnaces is also assumed to burn in the aftermath of the collapse. An instantaneous plus-resuspension ground-level release of 39 g (1.4 oz) of respirable plutonium is estimated for the process area. While the release of an additional 2,529 g (89 oz) from the vault would be possible, it would be unlikely given the expected packaging of materials in the vault. The estimated frequency of this accident is in the range of 10^{-5} to 10^{-7} per year.

Explosion. The bounding explosion is a deflagration of a hydrogen gas mixture inside the hydride oxidation (HYDOX) furnace. The deflagration is assumed to result from multiple equipment failures and operator errors that lead to a buildup of hydrogen and a flow of oxygen into the inert-atmosphere glovebox used in the HYDOX process. Also assumed is an MAR of 4.5 kg (9.9 lb) of plutonium powder, and given the venting of pressurized gas through the powder, bounding ARF and RF of 0.1 and 0.7, respectively. The explosive energy would be sufficient to damage glovebox windows but insufficient to threaten the building HEPA filter system. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 3.2×10^{-3} g (1.1×10^{-4} oz) is postulated. The estimated frequency of this accident is in the range of 10^{-2} to 10^{-4} per year.

Fire. According to the several safety analyses of the plutonium facility at LANL, the bounding fire within the pit conversion facility is a fire involving all of the gloves in a glovebox used for blending plutonium powder. A flammable cleaning liquid is assumed to be brought into the glovebox, in violation of procedure, then to spill and ignite. The gloves are assumed to be stowed outside the glovebox but to be ignited by the fire and completely consumed. An MAR of 2 g (0.07 oz) of plutonium dust is assumed for each of 12 gloves, with all of the 24 g (0.85 oz) assumed to be aerosolized. The sprinkler system is assumed to function and protect the room and remainder of the building. Also assumed are an ARF of 0.05 and an RF of 1.0, resulting in a 1.2-g (0.04-oz) release to the building ventilation system. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 1.2×10^{-5} g (4.2×10^{-7} oz) is postulated. The estimated frequency of this accident is in the range of 10^{-2} to 10^{-4} per year.

Leaks or Spills of Nuclear Material. The most catastrophic leak or spill postulated would result from a forklift or other large vehicle running over a package of nuclear material and breaching the storage container. If a 4-kg (8.8-lb) package of plutonium oxide were breached, a total airborne release of 0.44 g (0.016 oz) to the room would occur, and after HEPA filtration of the facility exhaust, a total release of 4.4×10^{-6}. This accident has an estimated frequency in the range of 10^{-4} to 10^{-6} per year.

Tritium Release. A major glovebox fire is assumed to heat multiple parts contaminated with up to 20 g (0.71 oz) of tritium and convert all of it into tritiated water vapor. Very conservatively, the ARF, RF, and LPF are all assumed to be 1.0, resulting in a release of 20 g (0.71 oz) (1.9×10^{-5} Ci) through the stack to the atmosphere. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year.

K.1.5.2.2 Immobilization Facility

A wide range of potential accident scenarios are reflected in the immobilization facility data reports (UC 1999a–d). The analysis assumes that the immobilization facility is located in a new or upgraded existing building designed to withstand design basis natural phenomena hazards such as earthquakes, winds, tornadoes, and floods such that no unfiltered releases would be expected. Also, no site-specific accidents conducive to releases are identified. Therefore, the potential accident scenarios apply to all four candidate sites. Additional discussion of scenario development based on consistency concerns can be found in Appendix K.1.5.1.

Analysis of the proposed process operations identified specific scenarios for the conversion process, each of the immobilization options (ceramic and glass), and the canister-handling portion of the process. Design basis and beyond-design-basis earthquakes were identified for the overall facility. Identified as accidents specific to the plutonium conversion processes were a criticality, an explosion in HYDOX furnace, a calcining furnace–glovebox fire, and a hydrogen explosion in the plutonium conversion room. For the ceramic immobilization option, moreover, a sintering furnace–glovebox fire was identified; for the glass immobilization option, a melter eruption and a melter spill. All of the scenarios identified with the canister-handling phase were negligible compared with the conversion and immobilization scenarios.

PLUTONIUM CONVERSION OPERATIONS

Criticality. Review of the possibility of accidents attributable to plutonium conversion operations indicated that the principal processes of concern include the halide wash operations, the HYDOX furnace, and the sorting/unpacking glovebox. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It is assumed that human error could result in multiple failures leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year. A bounding source term resulting from 10^{19} fissions is assumed.

Explosion in HYDOX Furnace. The bounding explosion is a deflagration of a hydrogen gas mixture inside the HYDOX furnace. The deflagration is assumed to result from multiple equipment failures and operator errors that lead to a buildup of hydrogen and a flow of oxygen into the inert-atmosphere glovebox used in the HYDOX process. Also assumed is an MAR of 4.8 kg (11 lb) of plutonium powder, and given the venting pressurized gas through the powder, bounding ARF and RF of 0.1 and 0.7, respectively. The explosive energy would be sufficient to damage glovebox windows but insufficient to threaten the building HEPA filter system. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 3.4×10^{-3} g (1.2×10^{-4} oz) is postulated. The estimated frequency of this accident is approximately 10^{-3} per year or in the unlikely range.

Hydrogen Explosion in Plutonium Conversion Room. A supply pipe leak in the plutonium conversion room could result in a hydrogen explosion. Conversion of plutonium metal is accomplished using the HYDOX process, which entails the introduction of hydrogen gas. Were the hydrogen supply piping to leak into the operating/maintenance room, the gas could be ignited by an electrical short or operating mechanical equipment, causing an explosion. Depending on the volume of the leak, the structural integrity of the glovebox glove ports could fail and disperse the plutonium oxide. It is assumed that the building ventilation does not fail, and that the two HEPA filters provide filtration prior to discharge of the powder to the stack. An entire day's inventory of 25 kg (55 lb) of plutonium oxide powder is assumed present in the plutonium conversion gloveboxes. Based on an ARF of 5×10^{-3}, an RF of 0.3, and an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 3.8×10^{-4} g (1.3×10^{-5} oz) of plutonium is postulated. The estimated frequency of this accident is approximately 10^{-3} per year or in the unlikely range.

Furnace-Initiated Glovebox Fire (Calcining Furnace). It is assumed that a fault in the calcining furnace results in the ignition of any combustibles (e.g., bags) left inside the glovebox. The fire would be self-limiting, but would cause suspension of the radioactive material. It is also assumed that the glovebox (including the window) maintains its structural integrity, but that the internal glovebox HEPA filter fails. All of the loose surface contamination within the glovebox, assumed to be 10 percent of the daily inventory (4.5 kg [9.9 lb] of plutonium) of the calcining furnace, is assumed to be involved. Based on an ARF of 6×10^{-3}, an RF of 0.01, and an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 2.7×10^{-7} g (9.5×10^{-9} oz) of plutonium is postulated. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year.

CERAMIC IMMOBILIZATION OPTION

Criticality. Review of the possibility of accidents attributable to the ceramic immobilization operations indicated that the principal operation of concern is the rotary splitter tumbler. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It is assumed that human error results in multiple failures leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year. A bounding source term resulting from 10^{19} fissions is assumed.

Design Basis Earthquake. The principal design basis natural phenomena event that could release material to the environment is the design basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system should continue to function, the vibratory motion would be expected to suspend loose plutonium powder within gloveboxes and cause some minor spills. These would be picked up by the ventilation system and filtered by the HEPA filters before release from the building. Most material storage containers are assumed to be engineered to withstand design basis earthquakes without failing. For plutonium conversion, it is assumed that at the time of the event the entire day's inventory (25 kg [55 lb] of plutonium) is present in the form of oxide powder. For the ceramic immobilization portion, this includes the oxide inventories from the rotary splitter, oxide grinding, blend and granulate feed storage, drying and storage, pressing, inspection, and load trays and weigh areas. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 38 g (1.3 oz) of plutonium to the still-functioning building ventilation system and 3.8×10^{-4} g (1.3×10^{-5} oz) from the stack. The nominal frequency estimate for a design basis earthquake affecting new DOE plutonium facilities is 5×10^{-4} per year, or in the unlikely range.

Beyond-Design-Basis Earthquake. The postulated beyond-design-basis earthquake is assumed to be of sufficient magnitude to cause total collapse of the process equipment, building walls, roof, and floors, and loss of the containment function of the building. The material in the building is assumed to be driven airborne by the seismic vibrations, free-fall during the collapse, and impact. Material in storage containers in vaults would be adequately protected from the scenario energetics. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 19 g (0.67 oz) of plutonium at ground level. The estimated frequency of this accident is in the range of 10^{-5} to 10^{-7} per year.

Furnace-Initiated Glovebox Fire (Sintering Furnace). It is assumed that the sintering gas supplied to the furnace gloveboxes is a safe gas mixture—hydrogen and argon. Human errors are at issue—either a vendor/supplier that causes a supply of air or noninerting gas to be supplied to the furnace glovebox, or a piping error at the facility itself, in which oxygen is inadvertently substituted for the inert gas. Any combustibles (e.g., bags) left inside the glovebox could ignite, causing a glovebox fire. It is assumed that the fire is self-limiting, but causes suspension of the radioactive material. It is also assumed that the glovebox (including the window) maintains its structural integrity, but that the internal glovebox HEPA filter fails. All of the loose surface contamination within the glovebox, assumed to be 10 percent of the daily inventory (25 kg [55 lb] of plutonium) of the calcining furnace, is assumed to be involved. Based on an ARF of 6×10^{-3}, an RF of 0.01, and an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 1.5×10^{-6} g (5.3×10^{-8} oz) of plutonium is postulated. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year.

GLASS IMMOBILIZATION OPTION

Design Basis Earthquake. The principal design basis natural phenomena event that could release material to the environment is the design basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system should continue to function, the vibratory motion would be expected to suspend loose plutonium powder within gloveboxes and cause some minor spills. These would be picked up by the ventilation system and filtered by the HEPA filters before release from the building. Most material storage containers are assumed to be engineered to withstand design basis earthquakes without failing. For plutonium conversion, it is assumed that at the time of the event the entire day's inventory (25 kg [55 lb] of plutonium) is present in the form of oxide powder. For the glass immobilization portion, this includes oxide inventories from the rotary splitter, oxide grinding, blend melter, and feed storage. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 33 g (1.2 oz) of plutonium to the still-functioning building ventilation system and 3.3×10^{-4} g (1.2×10^{-5} oz) from the stack. The nominal frequency estimate for a design basis earthquake affecting new DOE plutonium facilities is 5×10^{-4} per year, or in the unlikely range.

Beyond-Design-Basis Earthquake. The postulated beyond-design-basis earthquake is assumed to be of sufficient magnitude to cause total collapse of the process equipment, building walls, roof, and floors, and loss of the containment function of the building. The material in the building is assumed to be driven airborne by the seismic vibrations, free-fall during the collapse, and impact. Material in storage containers in vaults storage would be adequately protected from the scenario energetics. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 17 g (0.60 oz) of plutonium released at ground level. The estimated frequency of this accident is in the range of 10^{-5} to 10^{-7} per year.

Melter Eruption. A melter eruption could result from the buildup of impurities in, or addition of impurities to, the glass frit or melt. Impurities range from water, which could cause a steam eruption, to chemical contaminants, which could react at elevated temperatures and produce a highly exothermic reaction (eruption or deflagration). The resulting sudden pressure increase could eject the fissile material bearing melt liquid into the processing glovebox structure. However the energy release would likely be insufficient to challenge the glovebox structure. It is assumed that the entire contents of the melter, about 1.4 kg (3.1 lb) of plutonium, are ejected into the glovebox. Based on an ARF of 4×10^{-4}, an RF of 1, and an LPF of 1.0×10^{-5} for two HEPAs, a stack release of 1.4×10^{-6} g (4.9×10^{-8} oz) of plutonium is postulated. The estimated frequency of this accident is approximately 2.5×10^{-3} per year, or in the unlikely range.

Melter Spill. A melter spill into the glovebox could occur due to improper alignment of the product glass cans during pouring operations. The melter glovebox enclosure and the off-gas exhaust ventilation system would confine radioactive material released in the spill. The glovebox structure and its associated filtered exhaust ventilation system would not be impacted by this event. It is assumed that the entire contents of the melter, about 1.4 kg (3.1 lb) of plutonium, are spilled into the glovebox. On the basis of an ARF of 2.4×10^{-5}, a RF of 1, and an LPF of 1.0×10^{-5} for two HEPAs, a stack release of 3.3×10^{-7} g (1.2×10^{-8} oz) of plutonium is postulated. The estimated frequency of this accident is approximately 3×10^{-4} per year, or in the unlikely range.

CAN-IN-CANISTER OPERATIONS

Can-Handling Accident (Before Shipment to Vitrification Facility). A can-handling accident would involve a can containing either ceramic pellets or a vitrified glass log of plutonium material. Studies supporting the Defense Waste Processing Facility (DWPF) SAR (UC 1999a–d) indicate that the source term resulting from dropping or tipping a log of vitrified waste, even without credit for the steel canister, would be negligible. Both surplus plutonium immobilization technologies (ceramic and glass) result in a form with a durability that is comparable to that of the DWPF vitrified waste form. Consequently, no postulated can-handling event would result in a radioactive release to the environment.

Melter Spill (Melt Pour at Vitrification Facility). Analysis of a spill of melt material was included in studies performed in support of the DWPF SAR. According to that analysis, the source term resulting from the dropping or tipping a log of vitrified waste, even without credit for the steel canister, would be negligible. Both surplus plutonium immobilization technologies (ceramic and glass) result in a form with a durability that is comparable to the DWPF vitrified waste form. Consequently, it is postulated that no melter spill event results in a radioactive release to the environment.

Canister-Handling Accident (After Melt Pour at DWPF). Analysis of events involving the handling and storage of vitrified waste canisters was included in studies performed in support of the DWPF SAR. Results of that analysis indicate that the source term resulting from the dropping or tipping of a log of vitrified waste, even without credit for the steel canister, would be negligible. Both surplus plutonium immobilization technologies (ceramic and glass) result in a form with a durability that is comparable to the DWPF vitrified waste form. Consequently, it is postulated that no canister-handling event results in a radioactive release to the environment.

K.1.5.2.3 MOX Facility Accident Scenarios

A wide range of potential accident scenarios were considered in the analysis reflected in the MOX facility data reports (UC 1998b, 1998d, 1998g, 1998h). The analysis assumes that the MOX facility is located in a new or upgraded existing building designed to withstand design basis natural phenomena hazards such as earthquakes, winds, tornadoes, and floods such that no unfiltered releases would be expected. The MOX facility includes an aqueous plutonium-polishing process by which impurities, in particular gallium, are removed from the plutonium feed for MOX fuel fabrication. Bounding accidents for this process were developed separately from the accidents reflected in the MOX facility data reports and are documented in a stand-alone, process-specific data report (ORNL 1998).

Analysis of the proposed process operations for the MOX facility identified the following broad categories of accidents: aircraft crash (Pantex only), criticality, design basis earthquake, beyond-design-basis earthquake, explosion in sintering furnace, fire, and beyond-design-basis fire. Basic characteristics of each of these postulated accidents are described below. Additional discussion of scenario development based on consistency concerns can be found in Appendix K.1.5.1.

Aircraft Crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficiently to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative but would be expected to exceed those from the beyond-design-basis earthquake. At all sites except Pantex, the frequency of such a crash is below 10^{-7} per year.

Criticality. Review of the possibility of accidents for the MOX facility indicated no undue criticality risk associated with the proposed operations. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It is assumed that human error could result in multiple failures leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 10^{-4} to 10^{-6} per year. A bounding source term resulting from 10^{19} fissions in solution is assumed.

Design Basis Earthquake. The principal design basis natural phenomena event that could release material to the environment is the design basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system should continue to function, the vibratory motion would be expected to resuspend loose plutonium powder within gloveboxes and cause some minor spills. These would be picked up by the ventilation system and filtered by the HEPA filters before to release from the building. Material storage containers including cans, hoppers, and bulk storage vessels are assumed to be engineered to withstand design basis earthquakes without failing. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 4 g (0.14 oz) of plutonium (in the form of MOX powder) to the still-functioning building ventilation system and 4.0×10^{-5} g (3.5×10^{-7} oz) from the stack. The nominal frequency estimate for a design basis earthquake for new DOE plutonium facilities is 5×10^{-4} per year, or in the unlikely range.

Beyond-Design-Basis Earthquake. The postulated beyond-design-basis earthquake is assumed to be of sufficient magnitude to cause total collapse of the process equipment, building walls, roof, and floors, and loss of the containment function of the building. The material in the building is assumed to be driven airborne by the seismic vibrations, free-fall during the collapse, and impact. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 124 g (4.4 oz) of plutonium (in the form of MOX powder) at ground level. The estimated frequency of this accident is in the range of 10^{-5} to 10^{-7} per year.

Explosion in Sintering Furnace. The several furnaces proposed for the MOX fuel fabrication process all use nonexplosive mixtures of 6 percent hydrogen and 94 percent argon. Given the physical controls on the piping for nonexplosive and explosive gas mixtures, operating procedures, and other engineered safety controls, accidental use of an explosive gas is extremely unlikely, though not impossible. A bounding explosion or deflagration is postulated to occur in one of the three sintering furnaces in the MOX facility building. Multiple equipment failures and operator errors would be required to lead to a buildup of hydrogen and an inflow of oxygen into the inert furnace atmosphere. As much as 5.6 kg (12.3 lb) of plutonium in the form of MOX powder would be at risk, and a bounding ARF of 0.01 and RF of 1.0 is assumed. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 5.6×10^{-4} g (2.0×10^{-5} oz) of plutonium (in the form of MOX powder) is postulated. It is estimated that the frequency of this accident is in the range of 10^{-4} to 10^{-6} per year.

Ion Exchange Column Exotherm. A thermal excursion within an ion exchange column is postulated to result from offnormal operations, degraded resin, or a glovebox fire. It is also assumed that the column venting/pressure relief valve fails to vent the overpressure, causing the column to rupture violently. The overpressure releases plutonium nitrate solution as an aerosol within the affected glovebox, which in turn is processed through the ventilation system. If the overpressure also breaches the glovebox, a fraction of the aerosol is released within the room as well. The combined ARF and RF values for this scenario are 9.0×10^{-3} for burning resin and 6.0×10^{-3} for liquid behaving as a flashing spray on depressurization. Additionally, 10 percent of the resin is assumed to burn, yielding a combined ARF and RF value of 9.0×10^{-3} for loaded plutonium. The LPF for the ventilation system is 1.0×10^{-5}.

With regard to probability, process controls are used to ensure that nitrated anion exchange resins are maintained in a wet condition, that the maximum nitric acid concentration and the operating temperature are limited to safe values, and that the time for absorption of plutonium in the resin is minimized. With these controls in place, the frequency of this accident is estimated to be in the unlikely range.

Fire. It is assumed that the liquid organic solvent containing the maximum plutonium concentration leaks as a spray into the glovebox, builds to a flammable concentration, and is contacted by an ignition source. The combined ARF and RF value for this scenario is 1.0×10^{-2} for quiescent burning to self-extinguishment. The LPF for the ventilation system is 1.0×10^{-5}. Scenario frequency is assessed as unlikely.

Spill. Leakage of liquids from process equipment must be considered as an anticipated event. However, with multiple containment barriers, a release from the process room would be extremely unlikely. A bounding scenario involved a liquid spill of concentrated aqueous plutonium solution, with 50 l (13.2 gal) accumulating before the leak is stopped. The ARF and RF values used for this scenario are 2.0×10^{-4} and 0.5, respectively. The LPF for the building ventilation system is 1.0×10^{-5}.

Beyond-Design-Basis Fire. The MOX facility would be built and operated such that there would be insufficient combustible materials to support a large fire. To bound the possible consequences of a major fire, a large quantity of combustible materials are assumed to be introduced into the process area near the blending area, which contains a fairly large amount of plutonium. A major fire is assumed to occur that causes the building ventilation and filtration systems to fail, possibly due to clogged HEPA filters. A total of 11 kg (24 lb) of plutonium in the form of MOX powder is assumed at risk. Based on an ARF of 6×10^{-3}, a RF of 0.01, and an LPF of 1.4×10^{-2} for two damaged, clogged HEPA filters, a stack release of 9.4×10^{-3} g (3.3×10^{-4} oz) of plutonium (in the form of MOX powder) is postulated. It is estimated that the frequency of this accident is less than 10^{-6} per year.

K.1.5.2.4 Lead Assembly Accident Scenarios

Design basis and beyond-design-basis accident scenarios have been developed for the fabrication of MOX fuel lead assemblies. These scenarios are discussed in detail, with specific assumptions for each facility and site, in the site data reports (O'Connor et al. 1998a–e). In spite of efforts by all parties, however, some inconsistencies exist between the data reports. This does not imply technical inaccuracy in any analysis; it merely reflects the uncertainties and reliance on convention inherent in accident analyses in general. In preparing the accident analysis for the SPD EIS, therefore, information in the data reports was modified or augmented to ensure the consistency, as appropriate, that is necessary for a reliable comparison of lead assembly fabrication accidents and the other accidents analyzed herein. Modifications were made to ensure that, to the extent practical, differences in analytical results were based on actual differences in facility conditions, as opposed to arbitrary differences in analytical methods or assumptions. One change, reflected in Table K–2, involved the assumption for all accidents of an isotopic composition of plutonium identical to that assumed in the analyses of pit disassembly and conversion and MOX fuel fabrication.

Table K–2. Isotopic Composition of Plutonium Used in Lead Assembly Accident Analysis

Isotope	Weight Percent
Plutonium 238	3.0×10^{-2}
Plutonium 239	92.2
Plutonium 240	6.46
Plutonium 241	5.0×10^{-2}
Plutonium 242	1.0×10^{-1}
Americium 241	9.0×10^{-1}

Criticality. Criticalities could be postulated in several areas (e.g., powder storage, the gloveboxes involved in mixing, the furnace, the fuel rod storage area). The estimated frequencies associated with these events would vary depending on the controls in place, the number of operator movements, and the amount of fissile material present. A generic approach was taken with respect to the selection of the specifics of this event, rather than selection of a criticality scenario associated with a specific operation in the lead assembly fabrication.

The criticality source term stipulated in the data reports was modified to make it identical to the corresponding source term used in the assessment of criticality in the pit conversion, immobilization, and MOX facilities. That source term is based on a fission yield from 1.0×10^{19} fissions in an oxide powder. The discussion provided in Appendix K.1.5 on criticality is also applicable here.

Design Basis Earthquake. An earthquake appropriate with the facility's design basis was selected. For this event, major portions of the process line gloveboxes are assumed to be breached, making the contents available for release. The storage vault and receiving area are assumed to have suitable storage containers for plutonium oxide that would survive the earthquake (storage containers with double containment). In-process material in gloveboxes is, however, more vulnerable, as are powder storage areas that may exist. Of particular concerns are the dispersable powders at the powder-blending stations. Finished pellets and fuel rods are thought to be generally nondispersable, even though they could escape the gloveboxes. In this earthquake, some non-seismically qualified process equipment could fail, and some process material spill. It is also conservatively assumed that glovebox filtration would fail.

The lead assembly data reports use ARF and RF values of 1.0×10^{-2} and 0.2, respectively, for plutonium oxide in cans involved in a design basis earthquake. These values are based on DOE-HDBK-3010-94 recommendations for the suspension of bulk powder by debris impact and air turbulence from falling objects. For consistency with the design basis accident analyses for the other facilities, these values were changed to 1.0×10^{-3} and 0.1, values based on DOE-HDBK-3010-94 recommendations for the suspension of bulk powder due to vibration of substrate from shock-impact to powder confinement (e.g., gloveboxes, cans) due to external energy (e.g., seismic vibrations). Such values are appropriate for earthquakes in which structural integrity is largely maintained and there is not a significant amount of debris or falling objects.

Beyond-Design-Basis Earthquake. For this analysis an event much more severe in consequences than would be expected from the design basis earthquake was examined. For some existing DOE facilities, the estimated seismic frequencies of beyond-design-basis events can be greater than 1.0×10^{-6} per year. The design basis for every building in the complex varies considerably depending on site specifics, including the type of construction used in the building. A damage assessment of the facility is further complicated by the fact that seismic considerations could also be incorporated in the glovebox design of the facility. In reality, such a catastrophic event may or may not demolish the building and the gloveboxes. However, for the purposes of illustrating a high-consequence accident, total demolition of the building is assumed. In this event, no credit is taken for the building, filters, or gloveboxes.

In the data report, an estimated frequency of 1.0×10^{-6} per year is cited as appropriate. To acknowledge the high degree of uncertainty in assessing a frequency of this scenario, a range of extremely unlikely to beyond extremely unlikely has been assigned to this event.

The source term for the beyond-design-basis earthquake includes a contribution from the plutonium storage vault, the assumed DR being 5 percent. The values used for the ARF, RF and vault DR—1.0×10^{-3}, 0.3, and 0, respectively—derive from adjustments consistent with the analysis of the corresponding scenario in the MOX facility data report. This results in a reduction of the source term for this accident by a factor of 2, to 11 g (0.39 oz) plutonium.

Extensive analyses have been performed on the seismic hazard at LLNL and the response of the plutonium facility, Building 332, to that hazard. According to the geology and seismology studies characterizing the nature and magnitude of the seismic threat, there is no physiographic basis for postulating earthquake magnitudes and ground accelerations higher than Richter magnitude 6.9 and 1.1g, respectively. Building 332, Increment III, has been evaluated for resistance to earthquakes and ground accelerations of these magnitudes and found to be adequate. Events of significantly higher magnitude and ground acceleration would be required to collapse Increment III. The frequency of these larger events would most likely be extremely low (1.0×10^{-6} per year or less), as the physiography of the dominant fault systems is such that they are thought incapable of producing the required magnitudes of ground accelerations (Coats 1998). Results of a number of reviews of Increment III indicate that the actual ground motion needed to cause collapse of the structure is above 1.5g. Based on the current LLNL hazard curve and various estimates of the fragility curves for collapse of Increment III, the frequency of collapse is estimated at 1.0×10^{-7} per year or less (Murray 1998). The frequency of a total collapse of Building 332 at LLNL is thus considered sufficiently low that additional examination is unnecessary.

Explosion. An explosion event was postulated in the sintering furnace in the lead assembly fabrication facility. A nonexplosive mixture of 6 percent hydrogen and 94 percent argon is used in the furnace. Multiple equipment and operator errors would have to occur to enable the buildup of an explosive mixture of hydrogen and air in the box. It is assumed that green pellets are subjected to the direct force of the shock waves resulting from such an explosion. It is further assumed that the gloveboxes involved in powder blending are damaged indirectly by the explosion. It is not expected that the shock wave impacting this area would be severe enough to significantly damage all of the storage inventory because interim storage containers would provide some mitigation.

Fire. A moderate-size room fire is assumed. Combustible material such as hydraulic fluid, alcohol, or contaminated combustibles is assumed to be present in the room. Adjoining facilities such as offices conceivably add to the risk of fires in the building. The gloveboxes are assumed to fail in the fire. The MOX powder in interim storage is assumed to be at risk and subjected to the thermal stress of the fire, given failure of the gloveboxes. Because of the limited combustible material and mitigation features such as fire protection systems and a firefighting unit, the event is assumed to be terminated. This fire is not severe enough to jeopardize the overall confinement characteristics of the building.

The source term for the design basis fire analyzed in the lead assembly data reports is dominated by the explosive release of high pressure from two plutonium oxide cans as they are heated to the point of failure. The ARF and RF values for this phenomenon are 0.1 and 0.7, respectively, and reflect burst pressures on the order of 25 to 500 psig. The potential for this kind of release is highly uncertain, and a valid design basis fire may be defined without including it, as is the case with the data reports for the other facilities. Therefore, for greater consistency between the design basis fire for the lead assembly and those for the other facilities, it is assumed that the two plutonium oxide cans are already open and vulnerable to the same phenomena as the rest of the analyzed powder. This results in a reduction of the data report source term by a factor of 38.

It is noteworthy that the lead assembly data report assumes a room fire, and the other data reports, a process fire. This is not considered inconsistent: the lead assembly processes are expected to be closer to one another other than the MOX processes, so the potential for propagation of fire may be somewhat greater.

Beyond-Design-Basis Fire. Fuel-manufacturing operations do not involve the use of significant amounts of combustible material. For the purpose of analysis, the lead assembly data reports define a beyond-design-basis fire that results in building collapse, the breach of material in the plutonium storage vault, and a lofted plume. These assumptions, however, are inconsistent with the beyond-design-basis fires analyzed for the other facilities. The beyond-design-basis fire has therefore been modified to reflect a room fire or building fire that clogs the building HEPA filters, resulting in a ground-level, unfiltered release. The assumed LPF is 1.4×10^{-2} (Smith, Wilkey, and Siebe 1996), consistent with the other analyses. Additionally, it is assumed that the fire does not involve the vault or that the storage canisters in the vault provide adequate protection for the duration of the fire.

K.2 FACILITY ACCIDENT IMPACTS AT HANFORD

The potential source terms and consequences of postulated bounding facility accidents for each facility option at Hanford are presented in Tables K–3 through K–9. Accident scenarios and source terms were developed from data reports prepared for each technology. Consequences were estimated using the MACCS2 computer code and local population and meteorology data. The consequences are presented for mean and 95th percentile meteorological conditions.

Meteorological data are based on 10-m (33-ft) weather readings at Hanford for the 1996 calendar year.[5] In accordance with the MACCS2 format requirements, the data set consists of 8,760 consecutive hourly readings of windspeed, wind direction, Pasquill-Gifford stability class, and accumulated rainfall.

Population estimates for Hanford are for the year 2010, are based on the *Census of Population and Housing, 1990* (DOC 1992), and are identical to the estimates used for the analysis of normal operations in the SPD EIS. Population values are formatted into 16 sectors centered around the 16 standard compass directions, which are further subdivided into 10 radial distance intervals out to 80 km (50 mi).

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[5] The choice of calendar year was based primarily on data quality. For some combinations of site and calendar year, the data set contains significant gaps, making that data undesirable for use in dispersion modeling. As a result, not all sites were analyzed using meteorological data for the same calendar year.

Table K–3. Accident Impacts of Pit Conversion Facility in FMEF at Hanford

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Fire	1.2×10^{-5}	Unlikely	Mean	2.8×10^{-6}	1.1×10^{-9}	5.2×10^{-7}	2.6×10^{-10}	8.7×10^{-4}	4.3×10^{-7}
			95th percentile	1.1×10^{-5}	4.3×10^{-9}	1.6×10^{-6}	8.1×10^{-10}	5.3×10^{-3}	2.6×10^{-6}
Explosion	3.2×10^{-3}	Unlikely	Mean	7.3×10^{-4}	2.9×10^{-7}	1.4×10^{-4}	6.8×10^{-8}	2.3×10^{-1}	1.1×10^{-4}
			95th percentile	2.8×10^{-3}	1.1×10^{-6}	4.2×10^{-4}	2.1×10^{-7}	1.4	6.8×10^{-4}
Leaks/spills of nuclear material	4.4×10^{-6}	Extremely unlikely	Mean	1.0×10^{-6}	4.1×10^{-10}	1.9×10^{-7}	9.6×10^{-11}	3.2×10^{-4}	1.6×10^{-7}
			95th percentile	3.9×10^{-6}	1.6×10^{-9}	5.9×10^{-7}	3.0×10^{-10}	1.9×10^{-3}	9.5×10^{-7}
Tritium release	2.0×10^{1}	Extremely unlikely	Mean	1.2×10^{-1}	4.7×10^{-5}	2.2×10^{-2}	1.1×10^{-5}	3.7×10^{1}	1.8×10^{-2}
			95th percentile	4.5×10^{-1}	1.8×10^{-4}	6.8×10^{-2}	3.4×10^{-5}	2.2×10^{2}	1.1×10^{-1}
Criticality	1.0×10^{19} Fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Design basis earthquake	3.9×10^{-4}	Unlikely	Mean	9.0×10^{-5}	3.6×10^{-8}	1.7×10^{-5}	8.4×10^{-9}	2.8×10^{-2}	1.4×10^{-5}
			95th percentile	3.5×10^{-4}	1.4×10^{-7}	5.2×10^{-5}	2.6×10^{-8}	1.7×10^{-1}	8.4×10^{-5}
Beyond-design-basis fire	1.7×10^{-2}	Beyond extremely unlikely	Mean	2.9×10^{-2}	1.1×10^{-5}	1.1×10^{-3}	5.6×10^{-7}	1.5	7.7×10^{-4}
			95th percentile	1.1×10^{-1}	4.3×10^{-5}	4.1×10^{-3}	2.0×10^{-6}	9.9	4.9×10^{-3}
Beyond-design-basis earthquake	3.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	6.6×10^{1}	2.6×10^{-2}	2.6	1.3×10^{-3}	3.6×10^{3}	1.8
			95th percentile	2.5×10^{2}	9.9×10^{-2}	9.4	4.7×10^{-3}	2.3×10^{4}	11

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility.

Note: Calculated using the source terms in the pit conversion data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998a.

Table K–4. Accident Impacts of Ceramic Immobilization Facility in FMEF and HLWVF at Hanford (Hybrid Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts of Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	1.0×10^{-3}	4.0×10^{-7}	1.9×10^{-4}	9.4×10^{-8}	3.1×10^{-1}	1.6×10^{-4}
			95th percentile	3.8×10^{-3}	1.5×10^{-6}	5.8×10^{-4}	2.9×10^{-7}	1.9	9.4×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	8.0×10^{-8}	3.2×10^{-11}	1.5×10^{-8}	7.4×10^{-12}	2.5×10^{-5}	1.2×10^{-8}
			95th percentile	3.0×10^{-7}	1.2×10^{-10}	4.6×10^{-8}	2.3×10^{-11}	1.5×10^{-4}	7.4×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	1.1×10^{-4}	4.4×10^{-8}	2.1×10^{-5}	1.0×10^{-8}	3.4×10^{-2}	1.7×10^{-5}
			95th percentile	4.2×10^{-4}	1.7×10^{-7}	6.4×10^{-5}	3.2×10^{-8}	2.1×10^{-1}	1.0×10^{-4}
Glovebox fire (sintering furnace)	1.5×10^{-6}	Extremely unlikely	Mean	4.4×10^{-7}	1.8×10^{-10}	8.3×10^{-8}	4.1×10^{-11}	1.4×10^{-4}	6.9×10^{-8}
			95th percentile	1.7×10^{-6}	6.8×10^{-10}	2.6×10^{-7}	1.3×10^{-10}	8.3×10^{-4}	4.1×10^{-7}
Design basis earthquake	3.8×10^{-4}	Unlikely	Mean	1.1×10^{-4}	4.5×10^{-8}	2.1×10^{-5}	1.0×10^{-8}	3.5×10^{-2}	1.7×10^{-5}
			95th percentile	4.3×10^{-4}	1.7×10^{-7}	6.4×10^{-5}	3.2×10^{-8}	2.1×10^{-1}	1.0×10^{-4}
Beyond-design-basis fire	2.1×10^{-3}	Beyond extremely unlikely	Mean	4.5×10^{-3}	1.8×10^{-6}	1.8×10^{-4}	8.9×10^{-8}	2.4×10^{-1}	1.2×10^{-4}
			95th percentile	1.7×10^{-2}	6.8×10^{-6}	6.5×10^{-4}	3.2×10^{-7}	1.6	7.8×10^{-4}
Beyond-design-basis earthquake	1.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	4.1×10^{1}	1.6×10^{-2}	1.6	8.1×10^{-4}	2.2×10^{3}	1.1
			95th percentile	1.5×10^{2}	1.6×10^{-2}	5.8	2.9×10^{-3}	1.4×10^{4}	7.1

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility; HLWVF, high-level-waste vitrification facility, HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999a.

Table K–5. Accident Impacts of Glass Immobilization Facility in FMEF and HLWVF at Hanford (Hybrid Case)

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	1.0×10^{-3}	4.0×10^{-7}	1.9×10^{-4}	9.4×10^{-8}	3.1×10^{-1}	1.6×10^{-4}
			95th percentile	3.8×10^{-3}	1.5×10^{-6}	5.8×10^{-4}	2.9×10^{-7}	1.9	9.4×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	8.0×10^{-8}	3.2×10^{-11}	1.5×10^{-8}	7.4×10^{-12}	2.5×10^{-5}	1.2×10^{-8}
			95th percentile	3.0×10^{-7}	1.2×10^{-10}	4.6×10^{-8}	2.3×10^{-11}	1.5×10^{-4}	7.4×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	1.1×10^{-4}	4.4×10^{-8}	2.1×10^{-5}	1.0×10^{-8}	3.4×10^{-2}	1.7×10^{-5}
			95th percentile	4.2×10^{-4}	1.7×10^{-7}	6.4×10^{-5}	3.2×10^{-8}	2.1×10^{-1}	1.0×10^{-4}
Melter eruption	1.4×10^{-6}	Unlikely	Mean	4.1×10^{-7}	1.6×10^{-10}	7.6×10^{-8}	3.8×10^{-11}	1.3×10^{-4}	6.4×10^{-8}
			95th percentile	1.6×10^{-6}	6.3×10^{-10}	2.4×10^{-7}	1.2×10^{-10}	7.7×10^{-4}	3.8×10^{-7}
Melter spill	3.3×10^{-7}	Unlikely	Mean	9.6×10^{-8}	3.9×10^{-11}	1.8×10^{-8}	9.0×10^{-12}	3.0×10^{-5}	1.5×10^{-8}
			95th percentile	3.7×10^{-7}	1.5×10^{-10}	5.6×10^{-8}	2.8×10^{-11}	1.8×10^{-4}	9.0×10^{-8}
Design basis earthquake	3.3×10^{-4}	Unlikely	Mean	9.7×10^{-5}	3.9×10^{-8}	1.8×10^{-5}	9.1×10^{-9}	3.0×10^{-2}	1.5×10^{-5}
			95th percentile	3.7×10^{-4}	1.5×10^{-7}	5.6×10^{-5}	2.8×10^{-8}	1.8×10^{-1}	9.1×10^{-5}
Beyond-design-basis fire	3.8×10^{-4}	Beyond extremely unlikely	Mean	8.1×10^{-4}	3.3×10^{-7}	3.2×10^{-5}	1.6×10^{-8}	4.4×10^{-2}	2.2×10^{-5}
			95th percentile	3.1×10^{-3}	1.2×10^{-6}	1.2×10^{-4}	5.8×10^{-8}	2.8×10^{-1}	1.4×10^{-4}
Beyond-design-basis earthquake	1.7×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	3.6×10^{1}	1.4×10^{-2}	1.4	7.1×10^{-4}	1.9×10^{3}	9.7×10^{-1}
			95th percentile	1.4×10^{2}	5.4×10^{-2}	5.1	2.6×10^{-3}	1.2×10^{4}	6.2

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility; HLWVF, high-level-waste vitrification facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999b.

Table K–6. Accident Impacts of Ceramic Immobilization Facility in FMEF and HLWVF at Hanford (50-t Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	1.0×10^{-3}	4.0×10^{-7}	1.9×10^{-4}	9.4×10^{-8}	3.1×10^{-1}	1.6×10^{-4}
			95th percentile	3.8×10^{-3}	1.5×10^{-6}	5.8×10^{-4}	2.9×10^{-7}	1.9	9.4×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	8.0×10^{-8}	3.2×10^{-11}	1.5×10^{-8}	7.4×10^{-12}	2.5×10^{-5}	1.2×10^{-8}
			95th percentile	3.0×10^{-7}	1.2×10^{-10}	4.6×10^{-8}	2.3×10^{-11}	1.5×10^{-4}	7.4×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	1.1×10^{-4}	4.4×10^{-8}	2.1×10^{-5}	1.0×10^{-8}	3.4×10^{-2}	1.7×10^{-5}
			95th percentile	4.2×10^{-4}	1.7×10^{-7}	6.4×10^{-5}	3.2×10^{-8}	2.1×10^{-1}	1.0×10^{-4}
Glovebox fire (sintering furnace)	1.5×10^{-6}	Extremely unlikely	Mean	4.4×10^{-7}	1.8×10^{-10}	8.3×10^{-8}	4.1×10^{-11}	1.4×10^{-4}	6.9×10^{-8}
			95th percentile	1.7×10^{-6}	6.8×10^{-10}	2.6×10^{-7}	1.3×10^{-10}	8.3×10^{-4}	4.1×10^{-7}
Design basis earthquake	3.8×10^{-4}	Unlikely	Mean	1.0×10^{-4}	4.1×10^{-8}	1.9×10^{-5}	9.6×10^{-9}	3.2×10^{-2}	1.6×10^{-5}
			95th percentile	3.9×10^{-4}	1.6×10^{-7}	5.9×10^{-5}	3.0×10^{-8}	1.9×10^{-1}	9.6×10^{-5}
Beyond-design-basis fire	2.1×10^{-3}	Beyond extremely unlikely	Mean	4.5×10^{-3}	1.8×10^{-6}	1.8×10^{-4}	8.9×10^{-8}	2.4×10^{-1}	1.2×10^{-4}
			95th percentile	1.7×10^{-2}	6.8×10^{-6}	6.5×10^{-4}	3.2×10^{-7}	1.6	7.8×10^{-4}
Beyond-design-basis earthquake	1.9×10^{1}	Unlikely to beyond extremely unlikely	Mean	3.8×10^{1}	1.5×10^{-2}	1.5	7.4×10^{-4}	2.0×10^{3}	1.0
			95th percentile	1.4×10^{2}	5.7×10^{-2}	5.4	2.7×10^{-3}	1.3×10^{4}	6.5

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility; HLWVF, high-level-waste vitrification facility, HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999a.

Table K–7. Accident Impacts of Glass Immobilization Facility in FMEF and HLWVF at Hanford (50-t Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	1.0×10^{-3}	4.0×10^{-7}	1.9×10^{-4}	9.4×10^{-8}	3.1×10^{-1}	1.6×10^{-4}
			95th percentile	3.8×10^{-3}	1.5×10^{-6}	5.8×10^{-4}	2.9×10^{-7}	1.9	9.4×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	8.0×10^{-8}	3.2×10^{-11}	1.5×10^{-8}	7.4×10^{-12}	2.5×10^{-5}	1.2×10^{-8}
			95th percentile	3.0×10^{-7}	1.2×10^{-10}	4.6×10^{-8}	2.3×10^{-11}	1.5×10^{-4}	7.4×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	1.1×10^{-4}	4.4×10^{-8}	2.1×10^{-5}	1.0×10^{-8}	3.4×10^{-2}	1.7×10^{-5}
			95th percentile	4.2×10^{-4}	1.7×10^{-7}	6.4×10^{-5}	3.2×10^{-8}	2.1×10^{-1}	1.0×10^{-4}
Melter eruption	1.4×10^{-6}	Unlikely	Mean	4.1×10^{-7}	1.6×10^{-10}	7.6×10^{-8}	3.8×10^{-11}	1.3×10^{-4}	6.4×10^{-8}
			95th percentile	1.6×10^{-6}	6.3×10^{-10}	2.4×10^{-7}	1.2×10^{-10}	7.7×10^{-4}	3.8×10^{-7}
Melter spill	3.3×10^{-7}	Unlikely	Mean	9.6×10^{-8}	3.9×10^{-11}	1.8×10^{-8}	9.0×10^{-12}	3.0×10^{-5}	1.5×10^{-8}
			95th percentile	3.7×10^{-7}	1.5×10^{-10}	5.6×10^{-8}	2.8×10^{-11}	1.8×10^{-4}	9.0×10^{-8}
Design basis earthquake	3.3×10^{-4}	Unlikely	Mean	9.0×10^{-5}	3.6×10^{-8}	1.7×10^{-5}	8.4×10^{-9}	2.8×10^{-2}	1.4×10^{-5}
			95th percentile	3.5×10^{-4}	1.4×10^{-7}	5.2×10^{-5}	2.6×10^{-8}	1.7×10^{-1}	8.4×10^{-5}
Beyond-design-basis fire	3.8×10^{-4}	Beyond extremely unlikely	Mean	8.1×10^{-4}	3.3×10^{-7}	3.2×10^{-5}	1.6×10^{-8}	4.4×10^{-2}	2.2×10^{-5}
			95th percentile	3.1×10^{-3}	1.2×10^{-6}	1.2×10^{-4}	5.8×10^{-8}	2.8×10^{-1}	1.4×10^{-4}
Beyond-design-basis earthquake	1.7×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	3.3×10^{1}	1.3×10^{-2}	1.3	6.6×10^{-4}	1.8×10^{3}	9.0×10^{-1}
			95th percentile	1.3×10^{2}	5.0×10^{-2}	4.8	2.4×10^{-3}	1.2×10^{4}	5.8

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility; HLWVF, high-level-waste vitrification facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999b.

Table K–8. Accident Impacts of MOX Facility in FMEF at Hanford

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.1×10^{-2}	2.0×10^{-5}	6.5×10^{-3}	3.3×10^{-6}	6.2	3.1×10^{-3}
			95th percentile	1.5×10^{-1}	6.0×10^{-5}	1.9×10^{-2}	9.4×10^{-6}	3.9×10^{1}	1.9×10^{-2}
Explosion in sintering furnace	5.5×10^{-4}	Extremely unlikely	Mean	1.3×10^{-4}	5.1×10^{-8}	2.4×10^{-5}	1.2×10^{-8}	4.0×10^{-2}	2.0×10^{-5}
			95th percentile	4.9×10^{-4}	2.0×10^{-7}	7.4×10^{-5}	3.7×10^{-8}	2.4×10^{-1}	1.2×10^{-4}
Ion exchange exotherm	2.4×10^{-5}	Unlikely	Mean	5.6×10^{-6}	2.2×10^{-9}	1.0×10^{-6}	5.2×10^{-10}	1.7×10^{-3}	8.7×10^{-7}
			95th percentile	2.1×10^{-5}	8.6×10^{-9}	3.2×10^{-6}	1.6×10^{-9}	1.1×10^{-2}	5.2×10^{-6}
Fire	4.0×10^{-6}	Unlikely	Mean	9.3×10^{-7}	3.7×10^{-10}	1.7×10^{-7}	8.7×10^{-11}	2.9×10^{-4}	1.4×10^{-7}
			95th percentile	3.6×10^{-6}	1.4×10^{-9}	5.4×10^{-7}	2.7×10^{-10}	1.8×10^{-3}	8.7×10^{-7}
Spill	5.0×10^{-6}	Extremely unlikely	Mean	1.2×10^{-6}	4.7×10^{-10}	2.2×10^{-7}	1.1×10^{-10}	3.6×10^{-4}	1.8×10^{-7}
			95th percentile	4.5×10^{-6}	1.8×10^{-9}	6.7×10^{-7}	3.4×10^{-10}	2.2×10^{-3}	1.1×10^{-6}
Design basis earthquake	7.9×10^{-5}	Unlikely	Mean	1.8×10^{-5}	7.3×10^{-9}	3.4×10^{-6}	1.7×10^{-9}	5.7×10^{-3}	2.8×10^{-6}
			95th percentile	7.0×10^{-5}	2.8×10^{-8}	1.1×10^{-5}	5.3×10^{-9}	3.4×10^{-2}	1.7×10^{-5}
Beyond-design-basis fire	6.0×10^{-2}	Beyond extremely unlikely	Mean	1.0×10^{-1}	4.1×10^{-5}	4.0×10^{-3}	2.0×10^{-6}	5.5	2.8×10^{-3}
			95th percentile	3.8×10^{-1}	1.5×10^{-4}	1.5×10^{-2}	7.3×10^{-6}	3.5×10^{1}	1.8×10^{-2}
Beyond-design-basis earthquake	9.5×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.6×10^{2}	6.5×10^{-2}	6.4	3.2×10^{-3}	8.7×10^{3}	4.4
			95th percentile	6.1×10^{2}	2.4×10^{-1}	2.3×10^{1}	1.2×10^{-2}	5.6×10^{4}	2.8×10^{1}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FMEF, Fuels and Materials Examination Facility.

Note: Calculated using the source terms in the MOX data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998b.

Table K–9. Accident Impacts of New MOX Facility at Hanford

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.8×10^{-1}	7.2×10^{-5}	9.9×10^{-3}	4.9×10^{-6}	8.2	4.1×10^{-3}
			95th percentile	6.1×10^{-1}	2.5×10^{-4}	3.5×10^{-2}	1.7×10^{-5}	5.5×10^{1}	2.8×10^{-2}
Explosion in sintering furnace	5.5×10^{-4}	Extremely unlikely	Mean	8.0×10^{-4}	3.2×10^{-7}	3.5×10^{-5}	1.8×10^{-8}	5.0×10^{-2}	2.5×10^{-5}
			95th percentile	2.9×10^{-3}	1.2×10^{-6}	1.1×10^{-4}	5.7×10^{-8}	3.2×10^{-1}	1.6×10^{-4}
Ion exchange exotherm	2.4×10^{-5}	Unlikely	Mean	3.5×10^{-5}	1.4×10^{-8}	1.5×10^{-6}	7.7×10^{-10}	2.2×10^{-3}	1.1×10^{-6}
			95th percentile	1.3×10^{-4}	5.1×10^{-8}	5.0×10^{-6}	2.5×10^{-9}	1.4×10^{-2}	7.0×10^{-6}
Fire	4.0×10^{-6}	Unlikely	Mean	5.8×10^{-6}	2.3×10^{-9}	2.6×10^{-7}	1.3×10^{-10}	3.6×10^{-4}	1.8×10^{-7}
			95th percentile	2.1×10^{-5}	8.4×10^{-9}	8.3×10^{-7}	4.2×10^{-10}	2.3×10^{-3}	1.2×10^{-6}
Spill	5.0×10^{-6}	Extremely unlikely	Mean	7.3×10^{-6}	2.9×10^{-9}	3.2×10^{-7}	1.6×10^{-10}	4.5×10^{-4}	2.3×10^{-7}
			95th percentile	2.6×10^{-5}	1.1×10^{-8}	1.0×10^{-6}	5.2×10^{-10}	2.9×10^{-3}	1.5×10^{-6}
Design basis earthquake	7.9×10^{-5}	Unlikely	Mean	1.1×10^{-4}	4.6×10^{-8}	5.0×10^{-6}	2.5×10^{-9}	7.1×10^{-3}	3.6×10^{-6}
			95th percentile	4.1×10^{-4}	1.7×10^{-7}	1.6×10^{-5}	8.2×10^{-9}	4.6×10^{-2}	2.3×10^{-5}
Beyond-design-basis fire	6.0×10^{-2}	Beyond extremely unlikely	Mean	1.0×10^{-1}	4.1×10^{-5}	4.0×10^{-3}	2.0×10^{-6}	5.5	2.8×10^{-3}
			95th percentile	3.8×10^{-1}	1.5×10^{-4}	1.5×10^{-2}	7.3×10^{-6}	3.5×10^{1}	1.8×10^{-2}
Beyond-design-basis earthquake	9.5×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.6×10^{2}	6.5×10^{-2}	6.4	3.2×10^{-3}	8.7×10^{3}	4.4
			95th percentile	6.1×10^{2}	2.4×10^{-1}	2.3×10^{1}	1.2×10^{-2}	5.6×10^{4}	2.8×10^{1}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the MOX data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998b.

K.3 FACILITY ACCIDENT IMPACTS AT INEEL

The potential source terms and consequences of postulated bounding facility accidents for each facility option for INEEL are presented in Tables K–10 and K–11. Accident scenarios and source terms were developed from data reports prepared for each technology. Consequences were estimated using the MACCS2 computer code and local population and meteorology data. The consequences are presented for mean and 95th percentile meteorological conditions.

Meteorological data are based on 10-m (33-ft) weather readings at INEEL for the 1993 calendar year.[6] In accordance with MACCS2 format requirements, the data set consists of 8,760 consecutive hourly readings of windspeed, wind direction, Pasquill-Gifford stability class, and accumulated rainfall.

Population estimates for INEEL are for the year 2010, are based on the *Census of Population and Housing, 1990* (DOC 1992), and are identical to the estimates used for the analysis of normal operations in the SPD EIS. Population values are formatted into 16 sectors centered around the 16 standard compass directions, which are further subdivided into 10 radial distance intervals out to 80 km (50 mi).

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[6] The choice of calendar year was based primarily on data quality. For some combinations of site and calendar year, the data set contains significant gaps, making that data undesirable for use in dispersion modeling. As a result, not all sites were analyzed using meteorological data for the same calendar year.

Table K–10. Accident Impacts of Pit Conversion Facility in FPF at INEEL

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Fire	1.2×10^{-5}	Unlikely	Mean	2.5×10^{-6}	1.0×10^{-9}	3.0×10^{-7}	1.5×10^{-10}	5.6×10^{-5}	2.8×10^{-8}
			95th percentile	6.4×10^{-6}	2.5×10^{-9}	1.1×10^{-6}	5.3×10^{-10}	2.1×10^{-4}	1.0×10^{-7}
Explosion	3.2×10^{-3}	Unlikely	Mean	6.5×10^{-4}	2.6×10^{-7}	7.8×10^{-5}	3.9×10^{-8}	1.5×10^{-2}	7.4×10^{-6}
			95th percentile	1.7×10^{-3}	6.7×10^{-7}	2.8×10^{-4}	1.4×10^{-7}	5.5×10^{-2}	2.7×10^{-5}
Leaks/spills of nuclear material	4.4×10^{-6}	Extremely unlikely	Mean	9.1×10^{-7}	3.6×10^{-10}	1.1×10^{-7}	5.4×10^{-11}	2.1×10^{-5}	1.0×10^{-8}
			95th percentile	2.3×10^{-6}	9.3×10^{-10}	3.9×10^{-7}	1.9×10^{-10}	7.7×10^{-5}	3.8×10^{-8}
Tritium release	2.0×10^{1}	Extremely unlikely	Mean	1.0×10^{-1}	4.2×10^{-5}	1.2×10^{-2}	6.2×10^{-6}	2.4	1.2×10^{-3}
			95th percentile	2.7×10^{-1}	1.1×10^{-4}	4.5×10^{-2}	2.2×10^{-5}	8.8	4.4×10^{-3}
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	4.8×10^{-4}	2.4×10^{-7}	2.2×10^{-2}	1.1×10^{-5}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	1.6×10^{-3}	7.9×10^{-7}	8.5×10^{-2}	4.2×10^{-5}
Design basis earthquake	3.9×10^{-4}	Unlikely	Mean	8.0×10^{-5}	3.2×10^{-8}	9.5×10^{-6}	4.8×10^{-9}	1.8×10^{-3}	9.1×10^{-7}
			95th percentile	2.1×10^{-4}	8.2×10^{-8}	3.4×10^{-5}	1.7×10^{-8}	6.8×10^{-3}	3.4×10^{-6}
Beyond-design-basis fire	1.7×10^{-2}	Beyond extremely unlikely	Mean	3.0×10^{-2}	1.2×10^{-5}	8.1×10^{-4}	4.1×10^{-7}	9.6×10^{-2}	4.8×10^{-5}
			95th percentile	1.1×10^{-1}	4.5×10^{-5}	2.9×10^{-3}	1.5×10^{-6}	3.6×10^{-1}	1.8×10^{-4}
Beyond-design-basis earthquake	3.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	7.0×10^{1}	2.8×10^{-2}	1.9	9.3×10^{-4}	2.2×10^{2}	1.1×10^{-1}
			95th percentile	2.6×10^{2}	1.0×10^{-1}	6.7	3.3×10^{-3}	8.4×10^{2}	4.2×10^{-1}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 mi] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: FPF, Fuel Processing Facility.

Note: Calculated using the source terms in the pit conversion data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998f.

Table K–11. Accident Impacts of New MOX Facility at INEEL

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.9×10^{-1}	7.4×10^{-5}	4.3×10^{-3}	2.1×10^{-6}	2.7×10^{-1}	1.4×10^{-4}
			95th percentile	7.5×10^{-1}	3.0×10^{-4}	1.6×10^{-2}	8.2×10^{-6}	1.0	5.2×10^{-4}
Explosion in sintering furnace	5.5×10^{-4}	Extremely unlikely	Mean	8.3×10^{-4}	3.3×10^{-7}	2.2×10^{-5}	1.1×10^{-8}	3.1×10^{-3}	1.5×10^{-6}
			95th percentile	3.6×10^{-3}	1.4×10^{-6}	8.4×10^{-5}	4.2×10^{-8}	1.2×10^{-2}	5.8×10^{-6}
Ion exchange exotherm	2.4×10^{-5}	Unlikely	Mean	3.6×10^{-5}	1.4×10^{-8}	9.5×10^{-7}	4.8×10^{-10}	1.3×10^{-4}	6.7×10^{-8}
			95th percentile	1.6×10^{-4}	6.3×10^{-8}	3.7×10^{-6}	1.8×10^{-9}	5.1×10^{-4}	2.5×10^{-7}
Fire	4.0×10^{-6}	Unlikely	Mean	6.0×10^{-6}	2.4×10^{-9}	1.6×10^{-7}	7.9×10^{-11}	2.2×10^{-5}	1.1×10^{-8}
			95th percentile	2.6×10^{-5}	1.0×10^{-8}	6.1×10^{-7}	3.1×10^{-10}	8.5×10^{-5}	4.2×10^{-8}
Spill	5.0×10^{-6}	Extremely unlikely	Mean	7.5×10^{-6}	3.0×10^{-9}	2.0×10^{-7}	9.9×10^{-11}	2.8×10^{-5}	1.4×10^{-8}
			95th percentile	3.3×10^{-5}	1.3×10^{-8}	7.7×10^{-7}	3.8×10^{-10}	1.1×10^{-4}	5.3×10^{-8}
Design basis earthquake	7.9×10^{-5}	Unlikely	Mean	1.2×10^{-4}	4.7×10^{-8}	3.1×10^{-6}	1.6×10^{-9}	4.4×10^{-4}	2.2×10^{-7}
			95th percentile	5.1×10^{-4}	2.1×10^{-7}	1.2×10^{-5}	6.0×10^{-9}	1.7×10^{-3}	8.3×10^{-7}
Beyond-design-basis fire	6.0×10^{-2}	Beyond extremely unlikely	Mean	1.1×10^{-1}	4.3×10^{-5}	2.9×10^{-3}	1.4×10^{-6}	3.4×10^{-1}	1.7×10^{-4}
			95th percentile	4.1×10^{-1}	1.6×10^{-4}	1.0×10^{-2}	5.2×10^{-6}	1.3	6.5×10^{-4}
Beyond-design-basis earthquake	9.5×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.7×10^{2}	6.8×10^{-2}	4.6	2.3×10^{-3}	5.4×10^{2}	2.7×10^{-1}
			95th percentile	6.5×10^{2}	2.6×10^{-1}	1.6×10^{1}	8.2×10^{-3}	2.1×10^{3}	1.0
			95th percentile						

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the MOX data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998g.

K.4 FACILITY ACCIDENT IMPACTS AT PANTEX

The potential source terms and consequences of postulated bounding facility accidents for each facility option for Pantex are presented in Tables K–12 and K–13. Accident scenarios and source terms were developed from data reports prepared for each technology. Consequences were estimated using the MACCS2 computer code and local population and meteorology data. The consequences are presented for mean and 95th percentile meteorological conditions.

Meteorological data are based on 10-m (33-ft) weather readings from the Pantex Tower for the 1996 calendar year.[7] In accordance with MACCS2 format requirements, the data set consists of 8,760 consecutive hourly readings of windspeed, wind direction, Pasquill-Gifford stability class, and accumulated rainfall.

Population estimates for Pantex are for the year 2010, are based on the *Census of Population and Housing, 1990* (DOC 1992), and are identical to the estimates used for the analysis of normal operations in the SPD EIS. Population values are formatted into 16 sectors centered around the 16 standard compass directions, which are further subdivided into 10 radial distance intervals out to 80 km (50 mi).

[7] The choice of calendar year was based primarily on data quality. For some combinations of site and calendar year, the data set contains significant gaps, making that data undesirable for use in dispersion modeling. As a result, not all sites were analyzed using meteorological data for the same calendar year.

Table K–12. Accident Impacts of New Pit Conversion Facility at Pantex

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Fire	1.2×10^{-5}	Unlikely	Mean	2.3×10^{-6}	9.1×10^{-10}	7.6×10^{-7}	3.8×10^{-10}	1.8×10^{-4}	9.1×10^{-8}
			95th percentile	5.2×10^{-6}	2.1×10^{-9}	2.1×10^{-6}	1.0×10^{-9}	8.6×10^{-4}	4.3×10^{-7}
Explosion	3.2×10^{-3}	Unlikely	Mean	6.0×10^{-4}	2.4×10^{-7}	2.0×10^{-4}	9.9×10^{-8}	4.8×10^{-2}	2.4×10^{-5}
			95th percentile	1.4×10^{-3}	5.4×10^{-7}	5.4×10^{-4}	2.7×10^{-7}	2.2×10^{-1}	1.1×10^{-4}
Leaks/spills of nuclear material	4.4×10^{-6}	Extremely unlikely	Mean	8.4×10^{-7}	3.3×10^{-10}	2.8×10^{-7}	1.4×10^{-10}	6.7×10^{-5}	3.3×10^{-8}
			95th percentile	1.9×10^{-6}	7.6×10^{-10}	7.6×10^{-7}	3.8×10^{-10}	3.1×10^{-4}	1.6×10^{-7}
Tritium release	2.0×10^{1}	Extremely unlikely	Mean	9.6×10^{-2}	3.8×10^{-5}	3.2×10^{-2}	1.6×10^{-5}	7.7	3.8×10^{-3}
			95th percentile	2.2×10^{-1}	8.7×10^{-5}	8.7×10^{-2}	4.4×10^{-5}	3.6×10^{1}	1.8×10^{-2}
Criticality	1.0×10^{19} Fissions	Extremely unlikely	Mean	6.1×10^{-3}	2.5×10^{-6}	2.7×10^{-3}	1.3×10^{-6}	2.7×10^{-1}	1.4×10^{-4}
			95th percentile	1.5×10^{-2}	6.0×10^{-6}	6.0×10^{-3}	3.0×10^{-6}	1.6	7.9×10^{-4}
Design basis earthquake	3.9×10^{-4}	Unlikely	Mean	7.4×10^{-5}	2.9×10^{-8}	2.4×10^{-5}	1.2×10^{-8}	5.9×10^{-3}	2.9×10^{-6}
			95th percentile	1.7×10^{-4}	6.7×10^{-8}	6.7×10^{-5}	3.3×10^{-8}	2.8×10^{-2}	1.4×10^{-5}
Beyond-design-basis fire	1.7×10^{-2}	Beyond extremely unlikely	Mean	9.6×10^{-3}	3.8×10^{-6}	1.5×10^{-3}	7.5×10^{-7}	2.8×10^{-1}	1.4×10^{-4}
			95th percentile	2.8×10^{-2}	1.1×10^{-5}	4.4×10^{-3}	2.2×10^{-6}	1.3	6.3×10^{-4}
Beyond-design-basis earthquake	3.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	2.2×10^{1}	8.8×10^{-3}	3.5	1.7×10^{-3}	6.4×10^{2}	3.2×10^{-1}
			95th percentile	6.4×10^{1}	2.6×10^{-2}	1.0×10^{1}	5.1×10^{-3}	3.0×10^{3}	1.5
Aircraft crash	1.2×10^{2}	Beyond extremely unlikely	Mean	6.8×10^{1}	2.7×10^{-2}	1.1×10^{1}	5.4×10^{-3}	2.0×10^{3}	1.0
			95th percentile	2.0×10^{2}	7.9×10^{-2}	3.1×10^{1}	1.6×10^{-2}	9.2×10^{3}	4.5

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the pit conversion data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998e.

Table K–13. Accident Impacts of New MOX Facility at Pantex

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	7.5×10^{-2}	3.0×10^{-5}	1.9×10^{-2}	9.3×10^{-6}	1.9	9.4×10^{-4}
			95th percentile	2.4×10^{-1}	9.5×10^{-5}	4.7×10^{-2}	2.3×10^{-5}	1.1×10^{1}	5.4×10^{-3}
Explosion in sintering furnace	5.5×10^{-4}	Extremely unlikely	Mean	2.8×10^{-4}	1.1×10^{-7}	4.8×10^{-5}	2.4×10^{-8}	9.1×10^{-3}	4.5×10^{-6}
			95th percentile	8.9×10^{-4}	3.5×10^{-7}	1.3×10^{-4}	6.6×10^{-8}	4.2×10^{-2}	2.1×10^{-5}
Ion exchange exotherm	2.4×10^{-5}	Unlikely	Mean	1.2×10^{-5}	5.0×10^{-9}	2.1×10^{-6}	1.0×10^{-9}	4.0×10^{-4}	2.0×10^{-7}
			95th percentile	3.9×10^{-5}	1.5×10^{-8}	5.8×10^{-6}	2.9×10^{-9}	1.8×10^{-3}	9.0×10^{-7}
Fire	4.0×10^{-6}	Unlikely	Mean	2.1×10^{-6}	8.3×10^{-10}	3.5×10^{-7}	1.7×10^{-10}	6.6×10^{-5}	3.3×10^{-8}
			95th percentile	6.4×10^{-6}	2.6×10^{-9}	9.6×10^{-7}	4.8×10^{-10}	3.0×10^{-4}	1.5×10^{-7}
Spill	5.0×10^{-6}	Extremely unlikely	Mean	2.6×10^{-6}	1.0×10^{-9}	4.4×10^{-7}	2.2×10^{-10}	8.3×10^{-5}	4.1×10^{-8}
			95th percentile	8.1×10^{-6}	3.2×10^{-9}	1.2×10^{-6}	6.0×10^{-10}	3.8×10^{-4}	1.9×10^{-7}
Design basis earthquake	7.9×10^{-5}	Unlikely	Mean	4.1×10^{-5}	1.6×10^{-8}	6.8×10^{-6}	3.4×10^{-9}	1.3×10^{-3}	6.5×10^{-7}
			95th percentile	1.3×10^{-4}	5.1×10^{-8}	1.9×10^{-5}	9.4×10^{-9}	5.9×10^{-3}	3.0×10^{-6}
Beyond-design-basis fire	6.0×10^{-2}	Beyond extremely unlikely	Mean	3.4×10^{-2}	1.4×10^{-5}	5.4×10^{-3}	2.7×10^{-6}	1.0	5.0×10^{-4}
			95th percentile	9.9×10^{-2}	4.0×10^{-5}	1.6×10^{-2}	7.8×10^{-6}	4.6	2.3×10^{-3}
Beyond-design-basis earthquake	9.5×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	5.4×10^{1}	2.2×10^{-2}	8.5	4.3×10^{-3}	1.6×10^{3}	7.9×10^{-1}
			95th percentile	1.6×10^{2}	6.3×10^{-2}	2.5×10^{1}	1.2×10^{-2}	7.3×10^{3}	3.6
Aircraft crash	7.1×10^{2}	Beyond extremely unlikely	Mean	4.0×10^{2}	1.6×10^{-1}	6.3×10^{1}	3.2×10^{-2}	1.2×10^{4}	5.9
			95th percentile	1.2×10^{3}	4.7×10^{-1}	1.9×10^{2}	9.3×10^{-2}	5.4×10^{4}	2.7×10^{1}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the MOX data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998h.

K.5 FACILITY ACCIDENT IMPACTS AT SRS

The potential source terms and consequences of postulated bounding facility accidents for each facility option for SRS are presented in Tables K–14 through K–19. Accident scenarios and source terms were developed from data reports prepared for each technology. Consequences were estimated using the MACCS2 computer code and local population and meteorology data. The consequences are presented for both mean and 95th percentile meteorological conditions.

Meteorological data are based on 10-m (33-ft) weather readings at SRS, are identical to the data used in *F-Canyon Plutonium Solutions Environmental Impact Statement*, and included in Sample Problem D of the MACCS2 User's Guide (Chanin and Young 1997:4-4). In accordance with MACCS2 format requirements, the data set consists of 8,760 consecutive hourly readings of windspeed, wind direction, Pasquill-Gifford stability class, and accumulated rainfall.

Population estimates for SRS are for the year 2010, are based on the *Census of Population and Housing, 1990* (DOC 1992), and are identical to the estimates used for the analysis of normal operations in the SPD EIS. Population values are formatted into 16 sectors centered around the 16 standard compass directions, which are further subdivided into 10 radial distance intervals out to 80 km (50 mi).

[Tables deleted.]

Table K–14. Accident Impacts of New Pit Conversion Facility at SRS

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Proability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Fire	1.2×10^{-5}	Unlikely	Mean	2.6×10^{-6}	1.1×10^{-9}	2.1×10^{-7}	1.0×10^{-10}	5.4×10^{-4}	2.7×10^{-7}
			95th percentile	6.2×10^{-6}	2.5×10^{-9}	6.7×10^{-7}	3.3×10^{-10}	2.4×10^{-3}	1.2×10^{-6}
Explosion	3.2×10^{-3}	Unlikely	Mean	6.9×10^{-4}	2.8×10^{-7}	5.4×10^{-5}	2.7×10^{-8}	1.4×10^{-1}	7.0×10^{-5}
			95th percentile	1.6×10^{-3}	6.5×10^{-7}	1.8×10^{-4}	8.8×10^{-8}	6.2×10^{-1}	3.1×10^{-4}
Leaks/spills of nuclear material	4.4×10^{-6}	Extremely unlikely	Mean	9.6×10^{-7}	3.9×10^{-10}	7.5×10^{-8}	3.8×10^{-11}	2.0×10^{-4}	9.8×10^{-8}
			95th percentile	2.3×10^{-6}	9.1×10^{-10}	2.5×10^{-7}	1.2×10^{-10}	8.7×10^{-4}	4.3×10^{-7}
Tritium release	2.0×10^{1}	Extremely unlikely	Mean	1.1×10^{-1}	4.4×10^{-5}	8.6×10^{-3}	4.3×10^{-6}	2.3×10^{1}	1.1×10^{-2}
			95th percentile	2.6×10^{-1}	1.0×10^{-4}	2.8×10^{-2}	1.4×10^{-5}	1.0×10^{2}	5.0×10^{-2}
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	7.9×10^{-3}	3.2×10^{-6}	5.8×10^{-4}	2.9×10^{-7}	4.2×10^{-1}	2.1×10^{-4}
			95th percentile	1.7×10^{-2}	6.7×10^{-6}	1.8×10^{-3}	9.2×10^{-7}	1.8	9.0×10^{-4}
Design basis earthquake	3.9×10^{-4}	Unlikely	Mean	8.5×10^{-5}	3.4×10^{-8}	6.6×10^{-6}	3.3×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
			95th percentile	2.0×10^{-4}	8.0×10^{-8}	2.2×10^{-5}	1.1×10^{-8}	7.7×10^{-2}	3.8×10^{-5}
Beyond-design-basis fire	1.7×10^{-2}	Beyond extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	4.8×10^{-4}	2.4×10^{-7}	8.8×10^{-1}	4.4×10^{-4}
			95th percentile	4.0×10^{-2}	1.6×10^{-5}	1.6×10^{-3}	7.8×10^{-7}	3.7	1.9×10^{-3}
Beyond-design-basis earthquake	3.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	2.5×10^{1}	1.0×10^{-2}	1.1	5.5×10^{-4}	2.0×10^{3}	1.0
			95th percnetile	9.2×10^{1}	3.7×10^{-2}	3.6	1.8×10^{-3}	8.5×10^{3}	4.3

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] (or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the pit conversion data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998c.

Table K–15. Accident Impacts of Ceramic Immobilization Facility in New Construction and DWPF at SRS (Hybrid Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.3×10^{-3}	2.1×10^{-6}	4.6×10^{-4}	2.3×10^{-7}	3.5×10^{-1}	1.8×10^{-4}
			95th percentile	1.0×10^{-2}	4.2×10^{-6}	1.6×10^{-3}	7.8×10^{-7}	1.5	7.5×10^{-4}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	3.9×10^{-4}	1.6×10^{-7}	5.3×10^{-5}	2.7×10^{-8}	1.6×10^{-1}	7.8×10^{-5}
			95th percentile	8.6×10^{-4}	3.4×10^{-7}	1.6×10^{-4}	8.1×10^{-8}	7.1×10^{-1}	3.5×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	3.1×10^{-8}	1.2×10^{-11}	4.2×10^{-9}	2.1×10^{-12}	1.2×10^{-5}	6.2×10^{-9}
			95th percentile	6.8×10^{-8}	2.7×10^{-11}	1.3×10^{-8}	6.5×10^{-12}	5.6×10^{-5}	2.8×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	4.3×10^{-5}	1.7×10^{-8}	5.9×10^{-6}	2.9×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
			95th percentile	9.5×10^{-5}	3.8×10^{-8}	1.8×10^{-5}	9.0×10^{-9}	7.8×10^{-2}	3.8×10^{-5}
Glovebox fire (sintering furnace)	1.5×10^{-6}	Extremely unlikely	Mean	1.7×10^{-7}	6.9×10^{-11}	2.4×10^{-8}	1.2×10^{-11}	6.9×10^{-5}	3.4×10^{-8}
			95th percentile	3.8×10^{-7}	1.5×10^{-10}	7.2×10^{-8}	3.6×10^{-11}	3.1×10^{-4}	1.5×10^{-7}
Design basis earthquake	3.8×10^{-4}	Unlikely	Mean	4.4×10^{-5}	1.7×10^{-8}	5.9×10^{-6}	3.0×10^{-9}	1.7×10^{-2}	8.7×10^{-6}
			95th percentile	9.6×10^{-5}	3.8×10^{-8}	1.8×10^{-5}	9.1×10^{-9}	7.9×10^{-2}	3.9×10^{-5}
Beyond-design-basis fire	2.1×10^{-3}	Beyond extremely unlikely	Mean	1.7×10^{-3}	6.9×10^{-7}	7.6×10^{-5}	3.8×10^{-8}	1.4×10^{-1}	7.0×10^{-5}
			95th percentile	6.3×10^{-3}	2.5×10^{-6}	2.5×10^{-4}	1.2×10^{-7}	5.8×10^{-1}	2.9×10^{-4}
Beyond-design-basis earthquake	1.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.6×10^{1}	6.3×10^{-3}	6.8×10^{-1}	3.4×10^{-4}	1.3×10^{3}	6.3×10^{-1}
			95th percentile	5.7×10^{1}	2.3×10^{-2}	2.2	1.1×10^{-3}	5.3×10^{3}	2.7

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: DWPF, Defense Waste Processing Facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999c.

Table K–16. Accident Impacts of Glass Immobilization Facility in New Construction and DWPF at SRS (Hybrid Case)

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[a]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.3×10^{-3}	2.1×10^{-6}	4.6×10^{-4}	2.3×10^{-7}	3.5×10^{-1}	1.8×10^{-4}
			95th percentile	1.0×10^{-2}	4.2×10^{-6}	1.6×10^{-3}	7.8×10^{-7}	1.5	7.5×10^{-4}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	3.9×10^{-4}	1.6×10^{-7}	5.3×10^{-5}	2.7×10^{-8}	1.6×10^{-1}	7.8×10^{-5}
			95th percentile	8.6×10^{-4}	3.4×10^{-7}	1.6×10^{-4}	8.1×10^{-8}	7.1×10^{-1}	3.5×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	3.1×10^{-8}	1.2×10^{-11}	4.2×10^{-9}	2.1×10^{-12}	1.2×10^{-5}	6.2×10^{-9}
			95th percentile	6.8×10^{-8}	2.7×10^{-11}	1.3×10^{-8}	6.5×10^{-12}	5.6×10^{-5}	2.8×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	4.3×10^{-5}	1.7×10^{-8}	5.9×10^{-6}	2.9×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
			95th percentile	9.5×10^{-5}	3.8×10^{-8}	1.8×10^{-5}	9.0×10^{-9}	7.8×10^{-2}	3.8×10^{-5}
Melter eruption	1.4×10^{-6}	Unlikely	Mean	1.6×10^{-7}	6.4×10^{-11}	2.2×10^{-8}	1.1×10^{-11}	6.4×10^{-5}	3.2×10^{-8}
			95th percentile	3.5×10^{-7}	1.4×10^{-10}	6.7×10^{-8}	3.3×10^{-11}	2.9×10^{-4}	1.4×10^{-7}
Melter spill	3.3×10^{-7}	Unlikely	Mean	3.8×10^{-8}	1.5×10^{-11}	5.1×10^{-9}	2.6×10^{-12}	1.5×10^{-5}	7.5×10^{-9}
			95th percentile	8.3×10^{-8}	3.3×10^{-11}	1.6×10^{-8}	7.8×10^{-12}	6.8×10^{-5}	3.3×10^{-8}
Design basis earthquake	3.3×10^{-4}	Unlikely	Mean	3.8×10^{-5}	1.5×10^{-8}	5.2×10^{-6}	2.6×10^{-9}	1.5×10^{-2}	7.6×10^{-6}
			95th percentile	8.3×10^{-5}	3.3×10^{-8}	1.6×10^{-5}	7.9×10^{-9}	6.9×10^{-2}	3.4×10^{-5}
Beyond-design-basis fire	3.8×10^{-4}	Beyond extremely unlikely	Mean	3.1×10^{-4}	1.2×10^{-7}	1.4×10^{-5}	6.8×10^{-9}	2.5×10^{-2}	1.3×10^{-5}
			95th percentile	1.1×10^{-3}	4.6×10^{-7}	4.4×10^{-5}	2.2×10^{-8}	1.0×10^{-1}	5.3×10^{-5}
Beyond-design-basis earthquake	1.7×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.4×10^{1}	5.5×10^{-3}	6.0×10^{-1}	3.0×10^{-4}	1.1×10^{3}	5.5×10^{-1}
			95th percentile	5.0×10^{1}	2.0×10^{-2}	2.0	9.8×10^{-4}	4.6×10^{3}	2.3

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: DWPF, Defense Waste Processing Facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999d.

Table K–17. Accident Impacts of Ceramic Immobilization Facility in New Construction and DWPF at SRS (50-t Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.3×10^{-3}	2.1×10^{-6}	4.6×10^{-4}	2.3×10^{-7}	3.5×10^{-1}	1.8×10^{-4}
			95th percentile	1.0×10^{-2}	4.2×10^{-6}	1.6×10^{-3}	7.8×10^{-7}	1.5	7.5×10^{-4}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	3.9×10^{-4}	1.6×10^{-7}	5.3×10^{-5}	2.7×10^{-8}	1.6×10^{-1}	7.8×10^{-5}
			95th percentile	8.6×10^{-4}	3.4×10^{-7}	1.6×10^{-4}	8.1×10^{-8}	7.1×10^{-1}	3.5×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	3.1×10^{-8}	1.2×10^{-11}	4.2×10^{-9}	2.1×10^{-12}	1.2×10^{-5}	6.2×10^{-9}
			95th percentile	6.8×10^{-8}	2.7×10^{-11}	1.3×10^{-8}	6.5×10^{-12}	5.6×10^{-5}	2.8×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	4.3×10^{-5}	1.7×10^{-8}	5.9×10^{-6}	2.9×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
			95th percentile	9.5×10^{-5}	3.8×10^{-8}	1.8×10^{-5}	9.0×10^{-9}	7.8×10^{-2}	3.8×10^{-5}
Glovebox fire (sintering furnace)	1.5×10^{-6}	Extremely unlikely	Mean	1.7×10^{-7}	6.9×10^{-11}	2.4×10^{-8}	1.2×10^{-11}	6.9×10^{-5}	3.4×10^{-8}
			95th percentile	3.8×10^{-7}	1.5×10^{-10}	7.2×10^{-8}	3.6×10^{-11}	3.1×10^{-4}	1.5×10^{-7}
Design basis earthquake	3.8×10^{-4}	Unlikely	Mean	4.0×10^{-5}	1.6×10^{-8}	5.5×10^{-6}	2.7×10^{-9}	1.6×10^{-2}	8.0×10^{-6}
			95th percentile	8.8×10^{-5}	3.5×10^{-8}	1.7×10^{-5}	8.3×10^{-9}	7.2×10^{-2}	3.6×10^{-5}
Beyond-design-basis fire	2.1×10^{-3}	Beyond extremely unlikely	Mean	1.7×10^{-3}	6.9×10^{-7}	7.6×10^{-5}	3.8×10^{-8}	1.4×10^{-1}	7.0×10^{-5}
			95th percentile	6.3×10^{-3}	2.5×10^{-6}	2.5×10^{-4}	1.2×10^{-7}	5.8×10^{-1}	2.9×10^{-4}
Beyond-design-basis earthquake	1.9×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.4×10^{1}	5.7×10^{-3}	6.3×10^{-1}	3.1×10^{-4}	1.2×10^{3}	5.8×10^{-1}
			95th percentile	5.3×10^{1}	2.1×10^{-2}	2.1	1.0×10^{-3}	4.8×10^{3}	2.5

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: DWPF, Defense Waste Processing Facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999c.

Table K–18. Accident Impacts of Glass Immobilization Facility in New Construction and DWPF at SRS (50-t Case)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.3×10^{-3}	2.1×10^{-6}	4.6×10^{-4}	2.3×10^{-7}	3.5×10^{-1}	1.8×10^{-4}
			95th percentile	1.0×10^{-2}	4.2×10^{-6}	1.6×10^{-3}	7.8×10^{-7}	1.5	7.5×10^{-4}
Explosion in HYDOX furnace	3.4×10^{-3}	Unlikely	Mean	3.9×10^{-4}	1.6×10^{-7}	5.3×10^{-5}	2.7×10^{-8}	1.6×10^{-1}	7.8×10^{-5}
			95th percentile	8.6×10^{-4}	3.4×10^{-7}	1.6×10^{-4}	8.1×10^{-8}	7.1×10^{-1}	3.5×10^{-4}
Glovebox fire (calcining furnace)	2.7×10^{-7}	Extremely unlikely	Mean	3.1×10^{-8}	1.2×10^{-11}	4.2×10^{-9}	2.1×10^{-12}	1.2×10^{-5}	6.2×10^{-9}
			95th percentile	6.8×10^{-8}	2.7×10^{-11}	1.3×10^{-8}	6.5×10^{-12}	5.6×10^{-5}	2.8×10^{-8}
Hydrogen explosion	3.8×10^{-4}	Unlikely	Mean	4.3×10^{-5}	1.7×10^{-8}	5.9×10^{-6}	2.9×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
			95th percentile	9.5×10^{-5}	3.8×10^{-8}	1.8×10^{-5}	9.0×10^{-9}	7.8×10^{-2}	3.8×10^{-5}
Melter eruption	1.4×10^{-6}	Unlikely	Mean	1.6×10^{-7}	6.4×10^{-11}	2.2×10^{-8}	1.1×10^{-11}	6.4×10^{-5}	3.2×10^{-8}
			95th percentile	3.5×10^{-7}	1.4×10^{-10}	6.7×10^{-8}	3.3×10^{-11}	2.9×10^{-4}	1.4×10^{-7}
Melter spill	3.3×10^{-7}	Unlikely	Mean	3.8×10^{-8}	1.5×10^{-11}	5.1×10^{-9}	2.6×10^{-12}	1.5×10^{-5}	7.5×10^{-9}
			95th percentile	8.3×10^{-8}	3.3×10^{-11}	1.6×10^{-8}	7.8×10^{-12}	6.8×10^{-5}	3.3×10^{-8}
Design basis earthquake	3.3×10^{-4}	Unlikely	Mean	3.5×10^{-5}	1.4×10^{-8}	4.8×10^{-6}	2.4×10^{-9}	1.4×10^{-2}	7.0×10^{-6}
			95th percentile	7.7×10^{-5}	3.1×10^{-8}	1.5×10^{-5}	7.3×10^{-9}	6.4×10^{-2}	3.1×10^{-5}
Beyond-design-basis fire	3.8×10^{-4}	Beyond extremely unlikely	Mean	3.1×10^{-4}	1.2×10^{-7}	1.4×10^{-5}	6.8×10^{-9}	2.5×10^{-2}	1.3×10^{-5}
			95th percentile	1.1×10^{-3}	4.6×10^{-7}	4.4×10^{-5}	2.2×10^{-8}	1.0×10^{-1}	5.3×10^{-5}
Beyond-design-basis earthquake	1.7×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.3×10^{1}	5.1×10^{-3}	5.6×10^{-1}	2.8×10^{-4}	1.0×10^{3}	5.1×10^{-1}
			95th percentile	4.7×10^{1}	1.9×10^{-2}	1.8	9.1×10^{-4}	4.3×10^{3}	2.2

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: DWPF, Defense Waste Processing Facility; HYDOX, hydride oxidation.

Note: Calculated using the source terms in the immobilization data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1999d.

Table K–19. Accident Impacts of New MOX Facility at SRS

Accident	Source Term (g)	Frequency (per year)	Meteorology	Impacts on Noninvolved Worker: Dose (rem)	Impacts on Noninvolved Worker: Probability of Cancer Fatality[s]	Impacts at Site Boundary: Dose (rem)	Impacts at Site Boundary: Probability of Cancer Fatality[a]	Impacts on Population Within 80 km: Dose (person-rem)	Impacts on Population Within 80 km: Latent Cancer Fatalities[b]
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	8.8×10^{-2}	3.5×10^{-5}	4.0×10^{-3}	2.0×10^{-6}	3.9	1.9×10^{-3}
			95th percentile	3.0×10^{-1}	1.2×10^{-4}	1.6×10^{-2}	8.0×10^{-6}	1.6×10^{1}	8.0×10^{-3}
Explosion in sintering furnace	5.5×10^{-4}	Extremely unlikely	Mean	3.3×10^{-4}	1.3×10^{-7}	1.2×10^{-5}	6.1×10^{-9}	2.9×10^{-2}	1.4×10^{-5}
			95th percentile	1.2×10^{-3}	4.6×10^{-7}	4.8×10^{-5}	2.4×10^{-8}	1.2×10^{-1}	6.1×10^{-5}
Ion exchange exotherm	2.4×10^{-5}	Unlikely	Mean	1.4×10^{-5}	5.7×10^{-9}	5.3×10^{-7}	2.7×10^{-10}	1.2×10^{-3}	6.2×10^{-7}
			95th percentile	5.1×10^{-5}	2.0×10^{-8}	2.1×10^{-6}	1.1×10^{-9}	5.3×10^{-3}	2.7×10^{-6}
Fire	4.0×10^{-6}	Unlikely	Mean	2.4×10^{-6}	9.5×10^{-10}	8.9×10^{-8}	4.4×10^{-11}	2.1×10^{-4}	1.0×10^{-7}
			95th percentile	8.4×10^{-6}	3.4×10^{-9}	3.5×10^{-7}	1.8×10^{-10}	8.8×10^{-4}	4.4×10^{-7}
Spill	5.0×10^{-6}	Extremely unlikely	Mean	3.0×10^{-6}	1.2×10^{-9}	1.1×10^{-7}	5.6×10^{-11}	2.6×10^{-4}	1.3×10^{-7}
			95th percentile	1.1×10^{-5}	4.2×10^{-9}	4.4×10^{-7}	2.2×10^{-10}	1.1×10^{-3}	5.5×10^{-7}
Design basis earthquake	7.9×10^{-5}	Unlikely	Mean	4.6×10^{-5}	1.9×10^{-8}	1.7×10^{-6}	8.7×10^{-10}	4.1×10^{-3}	2.0×10^{-6}
			95th percentile	1.7×10^{-4}	6.6×10^{-8}	6.9×10^{-6}	3.5×10^{-9}	1.7×10^{-2}	8.7×10^{-6}
Beyond-design-basis fire	6.0×10^{-2}	Beyond extremely unlikely	Mean	3.9×10^{-2}	1.6×10^{-5}	1.7×10^{-3}	8.5×10^{-7}	3.2	1.6×10^{-3}
			95th percentile	1.4×10^{-1}	5.7×10^{-5}	5.6×10^{-3}	2.8×10^{-6}	1.3×10^{1}	6.7×10^{-3}
Beyond-design-basis earthquake	9.5×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	6.2×10^{1}	2.5×10^{-2}	2.7	1.4×10^{-3}	5.0×10^{3}	2.5
			95th percentile	2.3×10^{2}	9.1×10^{-2}	8.8	4.4×10^{-3}	2.1×10^{4}	1.1×10^{1}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or at the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Note: Calculated using the source terms in the MOX data report, as modified in Appendix K.1.5.1, site meteorology, projected regional population, and the MACCS2 computer code.

Source: UC 1998d.

K.6 LEAD ASSEMBLY ACCIDENT IMPACTS

Tables K–20 through K–25 present the source terms and accident impacts of fabrication of lead assemblies for the candidate sites.

Table K–20. Accident Impacts of Lead Assembly Fabrication at ANL–W

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	Source Term (g)	Frequency (per year)	Meteorology	Dose (rem)	Probability of Cancer Fatality[a]	Dose (rem)	Probability of Cancer Fatality[a]	Dose (person-rem)	Latent Cancer Fatalities[b]
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	2.5×10^{-2}	9.9×10^{-6}	1.3×10^{-3}	6.4×10^{-7}	6.8×10^{-2}	3.4×10^{-5}
			95th percentile	7.7×10^{-2}	3.1×10^{-5}	4.9×10^{-3}	2.5×10^{-6}	3.4×10^{-1}	1.7×10^{-4}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	5.0×10^{-5}	2.0×10^{-8}	2.0×10^{-6}	1.0×10^{-9}	5.1×10^{-4}	2.6×10^{-7}
			95th percentile	1.7×10^{-4}	6.8×10^{-8}	7.7×10^{-6}	3.9×10^{-9}	2.7×10^{-3}	1.4×10^{-6}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	2.2×10^{-5}	8.6×10^{-9}	8.7×10^{-7}	4.4×10^{-10}	2.2×10^{-4}	1.1×10^{-7}
			95th percentile	7.4×10^{-5}	2.9×10^{-8}	3.3×10^{-6}	1.7×10^{-9}	1.2×10^{-3}	5.9×10^{-7}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	3.5×10^{-4}	1.4×10^{-7}	1.4×10^{-5}	7.1×10^{-9}	3.6×10^{-3}	1.8×10^{-6}
			95th percentile	1.2×10^{-3}	4.8×10^{-7}	5.4×10^{-5}	2.7×10^{-8}	1.9×10^{-2}	9.6×10^{-6}
Beyond-design-basis earthquake	1.1×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	2.0×10^{1}	7.9×10^{-3}	7.7×10^{-1}	3.8×10^{-4}	1.5×10^{2}	7.4×10^{-2}
			95th percentile	7.4×10^{1}	3.0×10^{-2}	2.8	1.4×10^{-3}	7.9×10^{2}	3.9×10^{-1}
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	4.4×10^{-2}	1.8×10^{-5}	1.7×10^{-3}	8.5×10^{-7}	3.3×10^{-1}	1.6×10^{-4}
			95th percentile	1.7×10^{-1}	6.6×10^{-5}	6.2×10^{-3}	3.1×10^{-6}	1.8	8.7×10^{-4}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: ANL–W, Argonne National Laboratory–West.

Source: O'Connor et al. 1998a.

Table K–21. Accident Impacts of Lead Assembly Fabrication at Hanford (27-m Stack Height)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatalities[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.4×10^{-2}	5.6×10^{-6}	1.4×10^{-3}	6.8×10^{-7}	8.7×10^{-1}	4.3×10^{-4}
			95th percentile	4.0×10^{-2}	1.6×10^{-5}	4.2×10^{-3}	2.1×10^{-6}	5.5	2.7×10^{-3}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	1.6×10^{-5}	6.5×10^{-9}	1.9×10^{-6}	9.6×10^{-10}	2.9×10^{-3}	1.4×10^{-6}
			95th percentile	4.8×10^{-5}	1.9×10^{-8}	6.3×10^{-6}	3.2×10^{-9}	1.7×10^{-2}	8.6×10^{-6}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	7.1×10^{-6}	2.8×10^{-9}	8.4×10^{-7}	4.2×10^{-10}	1.2×10^{-3}	6.2×10^{-7}
			95th percentile	2.1×10^{-5}	8.4×10^{-9}	2.7×10^{-6}	1.4×10^{-9}	7.4×10^{-3}	3.7×10^{-6}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	1.1×10^{-4}	4.6×10^{-8}	1.4×10^{-5}	6.8×10^{-9}	2.0×10^{-2}	1.0×10^{-5}
			95th percentile	3.4×10^{-4}	1.4×10^{-7}	4.4×10^{-5}	2.2×10^{-8}	1.2×10^{-1}	6.0×10^{-5}
Beyond-design-basis earthquake	1.1×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.9×10^{1}	7.5×10^{-3}	7.4×10^{-1}	3.7×10^{-4}	1.0×10^{3}	5.1×10^{-1}
			95th percentile	7.1×10^{1}	8×10^{-2}	2.7	1.3×10^{-3}	6.5×10^{3}	3.2
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	4.1×10^{-2}	1.7×10^{-5}	1.6×10^{-3}	8.2×10^{-7}	2.2	1.1×10^{-3}
			95th percentile	1.6×10^{-1}	6.3×10^{-5}	5.9×10^{-3}	3.0×10^{-6}	1.4×10^{1}	7.2×10^{-3}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Source: O'Connor et al. 1998b.

Table K–22. Accident Impacts of Lead Assembly Fabrication at Hanford (36-m Stack Height)

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatalities[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	1.1×10^{-2}	4.4×10^{-6}	1.2×10^{-3}	6.0×10^{-7}	8.5×10^{-1}	4.3×10^{-4}
			95th percentile	3.3×10^{-2}	1.3×10^{-5}	3.4×10^{-3}	1.7×10^{-6}	5.4	2.7×10^{-3}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	9.1×10^{-6}	3.6×10^{-9}	1.7×10^{-6}	8.5×10^{-10}	2.8×10^{-3}	1.4×10^{-6}
			95th percentile	3.5×10^{-5}	1.4×10^{-8}	5.2×10^{-6}	2.6×10^{-9}	1.7×10^{-2}	8.5×10^{-6}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	3.9×10^{-6}	1.6×10^{-9}	7.3×10^{-7}	3.7×10^{-10}	1.2×10^{-3}	6.1×10^{-7}
			95th percentile	1.5×10^{-5}	6.0×10^{-9}	2.3×10^{-6}	1.1×10^{-9}	7.4×10^{-3}	3.7×10^{-6}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	6.4×10^{-5}	2.5×10^{-8}	1.2×10^{-5}	5.9×10^{-9}	2.0×10^{-2}	9.9×10^{-6}
			95th percentile	2.4×10^{-4}	9.8×10^{-8}	3.7×10^{-5}	1.8×10^{-8}	1.2×10^{-1}	5.9×10^{-5}
Beyond-design-basis earthquake	1.1×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.9×10^{1}	7.5×10^{-3}	7.4×10^{-1}	3.7×10^{-4}	1.0×10^{3}	5.1×10^{-1}
			95th percentile	7.1×10^{1}	2.8×10^{-2}	2.7	1.3×10^{-3}	6.5×10^{3}	3.2
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	4.1×10^{-2}	1.7×10^{-5}	1.6×10^{-3}	8.2×10^{-7}	2.2	1.1×10^{-3}
			95th percentile	1.6×10^{-1}	6.3×10^{-5}	5.9×10^{-3}	3.0×10^{-6}	1.4×10^{1}	7.2×10^{-3}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (single noninvolved worker at a distance of 1,000 m [3,281 ft] or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Source: O'Connor et al. 1998b.

Table K–23. Accident Impacts of Lead Assembly Fabrication at LLNL

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatalities[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	7.0×10^{-2}	2.8×10^{-5}	6.7×10^{-2}	3.3×10^{-5}	1.1×10^{1}	5.7×10^{-3}
			95th percentile	5.3×10^{-1}	2.1×10^{-4}	5.3×10^{-1}	2.7×10^{-4}	6.4×10^{1}	3.2×10^{-2}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	1.8×10^{-4}	7.2×10^{-8}	2.2×10^{-4}	1.1×10^{-7}	5.5×10^{-2}	2.8×10^{-5}
			95th percentile	1.3×10^{-3}	5.3×10^{-7}	1.7×10^{-3}	8.5×10^{-7}	2.8×10^{-1}	1.4×10^{-4}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	7.8×10^{-5}	3.1×10^{-8}	9.3×10^{-5}	4.7×10^{-8}	2.4×10^{-2}	1.2×10^{-5}
			95th percentile	5.7×10^{-4}	2.3×10^{-7}	7.4×10^{-4}	3.7×10^{-7}	1.2×10^{-1}	6.0×10^{-5}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	1.3×10^{-3}	5.0×10^{-7}	1.5×10^{-3}	7.6×10^{-7}	3.9×10^{-1}	1.9×10^{-4}
			95th percentile	9.3×10^{-3}	3.7×10^{-6}	1.2×10^{-2}	6.0×10^{-6}	1.9	9.7×10^{-4}
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	1.4×10^{-1}	5.7×10^{-5}	1.3×10^{-1}	6.7×10^{-5}	3.5×10^{1}	1.8×10^{-2}
			95th percentile	1.1	4.3×10^{-4}	1.1	5.3×10^{-4}	1.7×10^{2}	8.7×10^{-2}

[a] The closest point to the site boundary is 563 m (1,847 ft), which is less than 1,000 m (3,281 ft). Therefore, doses to the onsite worker are assessed at 1,000 m [3,281 ft] only in those directions where the site boundary is greater than 1,000 m (3,281 ft) away. For other directions, doses are assessed at the site boundary.

[b] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m (3,281 ft) or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: LLNL, Lawrence Livermore National Laboratory.

Note: A beyond-design-basis earthquake was not evaluated for Building 332 at LLNL because extensive analyses of the seismic hazard at the site and the response of the building to those hazards indicate that the scenario is beyond the range of "reasonably foreseeable." Current estimates are that the frequency of collapse is on the order of 1.0×10^{-7} per year or less.

Source: Murray 1998; O'Connor et al. 1998c.

Table K–24. Accident Impacts of Lead Assembly Fabrication at LANL

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatalities[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	2.2×10^{-2}	8.7×10^{-6}	1.1×10^{-2}	5.7×10^{-6}	1.5	7.5×10^{-4}
			95th percentile	6.5×10^{-2}	2.6×10^{-5}	2.8×10^{-2}	1.4×10^{-5}	6.6	3.2×10^{-3}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	3.4×10^{-5}	1.4×10^{-8}	1.3×10^{-5}	6.5×10^{-9}	3.1×10^{-3}	1.5×10^{-6}
			95th percentile	1.1×10^{-4}	4.3×10^{-8}	4.1×10^{-5}	2.1×10^{-8}	1.4×10^{-2}	6.8×10^{-6}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	1.5×10^{-5}	6.0×10^{-9}	5.7×10^{-6}	2.8×10^{-9}	1.3×10^{-3}	6.7×10^{-7}
			95th percentile	4.7×10^{-5}	1.9×10^{-8}	1.8×10^{-5}	9.0×10^{-9}	5.9×10^{-3}	2.9×10^{-6}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	2.4×10^{-4}	9.7×10^{-8}	9.2×10^{-5}	4.6×10^{-8}	2.2×10^{-2}	1.1×10^{-5}
			95th percentile	7.6×10^{-4}	3.0×10^{-7}	2.9×10^{-4}	1.5×10^{-7}	9.5×10^{-2}	4.8×10^{-5}
Beyond-design-basis earthquake	1.1×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	1.3×10^{1}	5.3×10^{-3}	4.4	2.2×10^{-3}	9.5×10^{2}	4.8×10^{-1}
			95th percentile	5.1×10^{1}	2.1×10^{-2}	1.4×10^{1}	7.0×10^{-3}	4.2×103	2.1
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	2.9×10^{-2}	1.2×10^{-5}	9.7×10^{-3}	4.9×10^{-6}	2.1	1.1×10^{-3}
			95th percentile	1.1×10^{-1}	4.6×10^{-5}	3.1×10^{-2}	1.6×10^{-5}	9.2	4.6×10^{-3}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Key: LANL, Los Alamos National Laboratory.

Source: O'Connor et al. 1998d.

Table K–25. Accident Impacts of Lead Assembly Fabrication at SRS H-Area

				Impacts on Noninvolved Worker		Impacts at Site Boundary		Impacts on Population Within 80 km	
Accident	**Source Term (g)**	**Frequency (per year)**	**Meteorology**	**Dose (rem)**	**Probability of Cancer Fatality[a]**	**Dose (rem)**	**Probability of Cancer Fatalities[a]**	**Dose (person-rem)**	**Latent Cancer Fatalities[b]**
Criticality	1.0×10^{19} fissions	Extremely unlikely	Mean	5.2×10^{-3}	2.1×10^{-6}	3.4×10^{-4}	1.7×10^{-7}	3.0×10^{-1}	1.5×10^{-4}
			95th percentile	1.0×10^{-2}	4.0×10^{-6}	9.3×10^{-4}	4.6×10^{-7}	1.3	6.5×10^{-4}
Design basis earthquake	3.9×10^{-5}	Unlikely	Mean	3.5×10^{-6}	1.4×10^{-9}	4.4×10^{-7}	2.2×10^{-10}	1.3×10^{-3}	6.3×10^{-7}
			95th percentile	7.8×10^{-6}	3.1×10^{-9}	1.3×10^{-6}	6.7×10^{-10}	5.6×10^{-3}	2.8×10^{-6}
Design basis fire	1.7×10^{-5}	Unlikely	Mean	1.5×10^{-6}	6.1×10^{-10}	1.9×10^{-7}	9.5×10^{-11}	5.4×10^{-4}	2.7×10^{-7}
			95th percentile	3.4×10^{-6}	1.3×10^{-9}	5.8×10^{-7}	2.9×10^{-10}	2.4×10^{-3}	1.2×10^{-6}
Design basis explosion	2.7×10^{-4}	Extremely unlikely	Mean	2.5×10^{-5}	9.9×10^{-9}	3.1×10^{-6}	1.5×10^{-9}	8.8×10^{-3}	4.4×10^{-6}
			95th percentile	5.5×10^{-5}	2.2×10^{-8}	9.5×10^{-6}	4.7×10^{-9}	3.9×10^{-2}	2.0×10^{-5}
Beyond-design-basis earthquake	1.1×10^{1}	Extremely unlikely to beyond extremely unlikely	Mean	7.1	2.9×10^{-3}	2.0×10^{-1}	9.8×10^{-5}	5.1×10^{2}	2.6×10^{-1}
			95th percentile	2.6×10^{1}	1.0×10^{-2}	8.8×10^{-1}	4.4×10^{-4}	2.2×10^{3}	1.1
			95th percentile						
Beyond-design-basis fire	2.4×10^{-2}	Beyond extremely unlikely	Mean	1.6×10^{-2}	6.3×10^{-6}	4.4×10^{-4}	2.2×10^{-7}	1.1	5.7×10^{-4}
			95th percentile	5.8×10^{-2}	2.3×10^{-5}	2.0×10^{-3}	9.8×10^{-7}	4.9	2.4×10^{-3}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single noninvolved worker at a distance of 1,000 m [3,281 ft] or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes that the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) if exposed to the indicated dose. The value assumes that the accident has occurred.

Source: O'Connor et al. 1998e.

K.7 COMMERCIAL REACTOR ACCIDENT ANALYSIS

K.7.1 Introduction

Postulated design basis and beyond-design-basis accidents were analyzed using the MACCS2 computer code for each of the three proposed reactor sites, Catawba Nuclear Station, McGuire Nuclear Station, and North Anna Power Station (NRC 1990, SNL 1997). Only those accidents with the potential for substantial radiological releases to the environment were evaluated. Two design basis accidents (a loss-of-coolant accident [LOCA] and a fuel-handling accident) and four beyond-design-basis accidents (a steam generator tube rupture, an early containment failure, a late containment failure, and an interfacing systems loss-of-coolant accident [ISLOCA]) meet this criteria. Each of these accidents was analyzed twice, once using the current low-enriched uranium (LEU) core, and again, assuming a partial (40 percent) MOX core. Doses (consequences) and risks to a noninvolved worker, the offsite MEI, and the general public within 80 km (50 mi) of each plant from each accident scenario were calculated. These results were then compared, by plant, for each postulated accident.

The MEI dose is calculated at the exclusion area boundary of each plant. The exclusion area boundary is that area surrounding the reactor in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided any one of these is not so close to the facility that it interferes with normal operation of the facility, and appropriate and effective arrangements are made to control traffic and protect public health and safety on the highway, railroad, or waterway in an emergency. There are generally no residences within an exclusion area. However, if there were residents, they would be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety would result.

K.7.2 Reactor Accident Identification and Quantification

Catawba and McGuire are similar plants, both with two 3,411-MWt Westinghouse pressurized water reactors (PWRs) with ice condenser containments. Because of these similarities, the release paths and mitigating mechanisms for the two plants are almost identical. The conservative assumptions of the NRC regulatory guidance produce identical radiological releases to the environment (source terms) for the two plants. However, site-specific population and meteorological inputs result in different consequences from the two plants. The North Anna site has two 2,893 MWt Westinghouse PWRs with subatmospheric containments.

Both the design basis and beyond-design-basis accidents were identified from plant documents. Design basis accidents were selected by reviewing the Updated Final Safety Analysis Report (UFSAR) for each plant (Duke Power 1996, 1997; Virginia Power 1998). Beyond-design-basis accidents were identified from the submittals (Duke Power 1991, 1992; Virginia Power 1992) in response to the NRC's Generic Letter 88–20 (NRC 1988), which required reactor licensees to perform Individual Plant Examinations (IPEs) for severe accident vulnerabilities. Source terms for each accident for LEU-only cores were identified from these documents, source terms for partial MOX cores were developed based on these LEU source terms, and analyses were performed assuming both the current LEU-only cores and partial MOX cores containing 40 percent MOX fuel and 60 percent LEU fuel. After the source term is developed, the consequences (in terms of LCFs and prompt fatalities) can be determined. To determine the risk, however, the frequency (probability) of occurrence of the accident must be determined. Then the consequences are multiplied by the frequency to determine the risk.

For this analysis, the frequencies of occurrence for the accidents with a 40 percent MOX core are assumed to be the same as those with an LEU core. The National Academy of Sciences reported (NAS 1995) that "any approach to the use of MOX fuel in U.S. power reactors must and will receive a thorough, formal safety review before it is licensed. While we are not in a position to predict what if any modifications to existing reactor types will be required as a result of such licensing reviews, we expect that the final outcome will be certification that whatever LWR type is chosen will be able, with modifications if appropriate, to operate within prevailing reactivity and thermal margins using sufficient plutonium loadings to accomplish the disposition mission in a small number of reactors. We believe, further, that under these circumstances no important overall adverse impact of MOX use ion the accident probabilities of the LWRs involved will occur; if there are adequate reactivity and thermal margins in the fuel, as licensing review should ensure, the main remaining determinants of accident probabilities will involve factors not related to fuel composition and hence unaffected by the use of MOX rather than LEU fuel." Considering the National Academy of Sciences statements, the lack of empirical data, and the degree of uncertainty associated with accident frequencies, this analysis assumes that the accident frequencies are the same for a 40 percent MOX core as those for a 100 percent LEU core.

K.7.2.1 MOX Source Term Development

MOX source terms were developed by applying the calculated ratio for individual radioisotopes present in both the MOX and LEU cores to the source term for each of the LEU accidents. MOX source term development required several steps. The analysis assumes that the initial isotopic composition of the plutonium is that delivered to the MOX facility for fabrication into MOX fuel. The MOX facility includes a polishing step that removes impurities, including americium 241, a major contributor to the dose from plutonium 235. This analysis conservatively assumes that the polishing step reduces the americium 241 to 1 part per million (ppm), then ages the plutonium for 1 year after polishing prior to being loaded into a reactor. Table K–26 provides the assumed isotopic composition for the plutonium source material.

Table K–26. Isotopic Breakdown of Plutonium

Isotope	Prior to Polishing (wt %)	After Polishing and Aging (wt %)
Plutonium 236	<1 ppb	1 ppb
Plutonium 238	0.03	0.03
Plutonium 239	92.2	93.28
Plutonium 240	6.46	6.54
Plutonium 241	0.05	0.05
Plutonium 242	0.1	0.1
Americium 241	0.9	25 ppm

Key: ppb, parts per billion; ppm, parts per million; wt %, weight percent.

The SPD EIS assumes that MOX fuel would be fabricated using depleted uranium (0.25 weight percent uranium 235) (White 1997). The MOX assemblies are assumed to be 4.37 percent plutonium/americium and the LEU assemblies are assumed to be 4.37 percent uranium 235. To simulate a normal plant refueling cycle, the MOX portion was assumed to be 50 percent once-burned and 50 percent twice-burned assemblies. The LEU portion of the MOX was assumed to be 33.3 percent once-burned, 33.3 percent twice-burned, and 33.3 percent thrice-burned assemblies. The LEU-only cores were assumed to be equally divided between once-, twice-, and thrice-burned assemblies. All analyses assumed end-of-cycle inventories to produce the highest consequences. Fuel cycles were based on an 18-month refueling schedule with a 40-day downtime between cycles. The source terms for the LEU-only accident analyses were those identified in plant documents. Source terms for the partial MOX cores were developed using the isotopic ratios in Table K–27 provided by Oak Ridge National Laboratory (ORNL 1999). The MOX core inventory for each isotope was divided by the LEU core inventory for that isotope to provide a MOX/LEU ratio for each isotope. These ratios were then applied to LEU releases for each accident to estimate the MOX releases.

Table K–27. MOX/LEU Core Inventory Isotopic Ratios

Isotope	Ratio	Isotope	Ratio	Isotope	Ratio
Americium 241	2.06	Krypton 85m	0.86	Strontium 91	0.86
Antimony 127	1.15	Krypton 87	0.85	Strontium 92	0.89
Antimony 129	1.07	Krypton 88	0.84	Technetium 99m	0.99
Barium 139	0.97	Lanthanum 140	0.97	Tellurium 127	1.16
Barium 140	0.98	Lanthanum 141	0.97	Tellurium 127m	1.20
Cerium 141	0.98	Lanthanum 142	0.97	Tellurium 129	1.08
Cerium 143	0.95	Molybdenum 99	0.99	Tellurium 129m	1.09
Cerium 144	0.91	Neodymium 147	0.98	Tellurium 131m	1.11
Cesium 134	0.85	Neptunium 239	0.99	Tellurium 132	1.01
Cesium 136	1.09	Niobium 95	0.94	Tritium	0.95
Cesium 137	0.91	Plutonium 238	0.76	Xenon 131m	1.02
Cobalt 58	0.86	Plutonium 239	2.06	Xenon 133	1.00
Cobalt 60	0.72	Plutonium 240	2.20	Xenon 133m	1.01
Curium 242	1.43	Plutonium 241	1.79	Xenon 135	1.28
Curium 244	0.94	Praseodymium 143	0.95	Xenon 135m	1.04
Iodine 131	1.03	Rhodium 105	1.19	Xenon 138	0.96
Iodine 132	1.02	Rubidium 86	0.77	Yttrium 90	0.76
Iodine 133	1.00	Ruthenium 103	1.11	Yttrium 91	0.85
Iodine 134	0.98	Ruthenium 105	1.18	Yttrium 92	0.89
Iodine 135	1.00	Ruthenium 106	1.28	Yttrium 93	0.91
Krypton 83m	0.89	Strontium 89	0.83	Zirconium 95	0.94
Krypton 85	0.78	Strontium 90	0.75	Zirconium 97	0.98

The NRC licensing process will thoroughly review precise enrichments and fuel management schemes. The enrichments and fuel management schemes analyzed in the SPD EIS were chosen as realistic upper bounds. The accidents also assumed a maximum 40 percent MOX core. Taken together, these assumptions are sufficiently conservative to account for uncertainties associated with the MOX/LEU ratios.

K.7.2.2 Meteorological Data

Meteorological data for each specific reactor site were used. The meteorological data characteristic of the site region are described by 1 year of hourly data (8,760 measurements). This data includes wind speed, wind direction, atmospheric stability, and rainfall (DOE 1999b).

K.7.2.3 Population Data

The population distribution around each plant was determined using 1990 census data extrapolated to the year 2015. The population was then split into segments that correspond to the chosen polar coordinate grid. The polar coordinate grid for this analysis consists of 12 radial intervals aligned with the 16 compass directions. For Catawba and McGuire, the distances (in kilometers) of the 12 radial intervals are: 0.64, 0.762, 1.61, 3.22, 4.83, 6.44, 8.05, 16.09, 32.18, 48.27, 64.36, 80.45. For North Anna, these distances (in kilometers) are: 0.64, 1.350, 1.61, 3.22, 4.83, 6.44, 8.05, 16.09, 32.18, 48.27, 64.36, 80.45. The first of the 12 segments represents the location of the noninvolved worker and the second is the location of the site boundary. Projected population data for the year 2015 corresponding to the grid segments at Catawba, McGuire, and North Anna are presented in Tables K–28, K–29, and K–30, respectively.

Table K–28. Projected Catawba Population for Year 2015

	Distance in Kilometers From Release Point											
Direction	**0.64**	**0.762**	**1.61**	**3.22**	**4.83**	**6.44**	**8.05**	**16.09**	**32.18**	**48.27**	**64.36**	**80.45**
N	0	0	6	14	73	469	800	2,642	51,540	31,112	49,551	33,306
NNE	0	0	6	112	250	334	362	9,394	173,036	135,229	102,558	66,298
NE	0	0	7	119	239	394	595	6,442	212,814	143,650	22,571	20,108
ENE	0	0	11	81	504	1,409	1,042	5,842	72,488	52,784	32,588	10,919
E	0	0	21	5	863	1,059	570	7,959	12,144	27,800	22,844	10,995
ESE	0	0	23	47	295	388	679	7,449	8,607	18,196	12,293	9,290
SE	0	0	20	25	284	893	1,060	37,300	14,279	14,657	12,776	3,692
SSE	0	0	6	80	278	706	891	16,458	10,249	4,190	1,599	11,376
S	0	0	24	165	275	606	819	4,529	4,457	15,062	1,579	1,874
SSW	0	0	17	137	245	238	346	2,268	3,563	2,093	12,970	4,245
SW	0	0	20	114	162	208	267	5,538	9,559	2,040	11,272	12,302
WSW	0	0	21	84	159	205	257	2,493	4,756	8,947	31,712	80,518
W	0	0	23	113	202	272	345	4,979	6,978	17,182	26,070	35,091
WNW	0	0	23	103	199	283	363	3,011	17,814	32,751	29,031	8,706
NW	0	0	23	96	165	274	363	3,099	65,856	28,474	33,819	45,793
NNW	0	0	21	85	125	1,153	1,296	3,404	48,431	24,219	32,537	52,530

Table K–29. Projected McGuire Population for Year 2015

	Distance in Kilometers From Release Point											
Direction	**0.64**	**0.762**	**1.61**	**3.22**	**4.83**	**6.44**	**8.05**	**16.09**	**32.18**	**48.27**	**64.36**	**80.45**
N	0	0	44	0	269	110	203	3,153	14,870	28,254	12,987	15,726
NNE	0	0	28	0	124	569	1,728	9,493	21,903	12,317	24,826	43,937
NE	0	0	30	0	5	832	1,016	6,944	30,939	44,064	55,186	44,691
ENE	0	0	184	144	405	684	591	4,289	51,928	37,373	13,039	28,160
E	0	0	217	180	448	381	493	7,575	26,495	21,992	16,957	14,635
ESE	0	0	65	69	271	381	507	7,423	119,345	79,039	36,221	26,552
SE	0	0	15	59	130	244	273	8,387	219,183	204,614	46,100	24,527
SSE	0	0	15	59	99	138	100	9,530	90,900	95,688	79,859	15,954
S	0	0	14	83	165	182	165	6,429	35,178	21,241	41,638	9,071
SSW	0	0	18	101	169	240	221	3,261	61,514	29,814	10,774	9,327
SW	0	0	26	101	169	236	305	5,338	20,195	31,064	47,641	43,067
WSW	0	0	19	101	169	236	296	2,741	20,873	17,334	15,815	15,077
W	6	0	14	112	184	252	312	2,048	24,932	11,715	12,705	43,357
WNW	0	0	3	101	444	811	338	2,187	14,985	57,262	74,708	60,953
NW	0	0	0	224	200	1,005	793	4,260	8,528	22,380	26,093	12,511
NNW	0	0	0	0	4	0	36	1,989	8,570	40,993	13,101	10,686

Table K–30. Projected North Anna Population for Year 2015

	Distance in Kilometers From Release Point											
Direction	**0.64**	**1.35**	**1.61**	**3.22**	**4.83**	**6.44**	**8.05**	**16.09**	**32.18**	**48.27**	**64.36**	**80.45**
N	0	0	0	39	98	122	153	576	7,816	5,149	17,803	42,233
NNE	0	0	2	37	58	160	206	1,236	7,634	10,765	25,976	172,658
NE	0	0	2	30	43	94	100	1,122	38,833	90,820	34,429	77,097
ENE	0	0	0	15	103	40	64	1,373	5,822	6,693	11,426	17,324
E	0	0	0	17	112	42	34	1,183	6,128	5,175	1,839	4,296
ESE	0	0	2	7	17	97	135	950	5,595	5,454	5,161	7,909
SE	0	0	1	18	77	9	12	575	2,989	19,343	59,057	76,396
SSE	0	0	3	50	29	27	40	919	5,051	15,259	443,326	392,420
S	0	0	0	42	20	30	40	669	4,413	11,763	20,254	34,375
SSW	0	0	0	10	12	54	65	554	3,098	5,803	5,616	6,222
SW	0	0	0	4	14	54	86	1,186	2,678	2,845	5,482	4,576
WSW	0	0	0	19	42	31	63	1,381	4,402	6,729	8,905	8,094
W	0	0	0	31	24	24	29	466	2,883	4,529	109,205	21,748
WNW	0	0	0	30	79	52	29	606	2,725	8,371	17,931	9,934
NW	0	0	1	35	52	92	81	662	3,327	11,604	11,816	3,090
NNW	0	0	0	28	64	13	25	771	4,725	9,040	25,534	10,041

K.7.2.4 Design Basis Events

Design basis events are defined by the American Nuclear Society as Condition IV occurrences or limiting faults. Condition IV occurrences are faults which are not expected to take place, but are postulated because their consequences would include the potential for the release of substantial radioactive material. These are the most serious events which must be designed against and represent limiting design cases.

The accident analyses presented in the UFSARs are conservative design basis analyses and therefore the dose consequences are bounding (i.e., a realistically based analysis would result in lower doses). The results, however, provide a comparison of the potential consequences resulting from design basis accidents. The consequences also provide insight into which design basis accidents should be analyzed in an environmental impact statement, such as the SPD EIS. After reviewing the UFSAR accident analyses, the design basis accidents chosen for evaluation in the SPD EIS are a large-break LOCA and a fuel-handling accident.

LOCA. A design basis large-break LOCA was chosen for evaluation because it is the limiting reactor design basis accident at each of the three plants. The analysis was performed in accordance with the methodology and assumptions in Regulatory Guide 1.4 (NRC 1974). The large-break LOCA is defined as a break equivalent in size to a double-ended rupture of the largest pipe of the reactor coolant system. Following a postulated double-ended rupture of a reactor coolant pipe, the emergency core cooling system keeps cladding temperatures well below melting, ensuring that the core remains intact and in a coolable geometry. As a result of the increase in cladding temperature and rapid depressurization of the core, however, some cladding failure may occur in the hottest regions of the core. Thus, a fraction of the fission products accumulated in the pellet-cladding gap may be released to the reactor coolant system and thereby to the containment. Although no core melting would occur for the design basis LOCA, a gross release of fission products is evaluated. The only postulated mechanism for such a release would require a number of simultaneous and extended failures to occur in the engineered safety feature systems, producing severe physical degradation of core geometry and partial melting of the fuel.

Development of the LOCA source term is based on the conservative assumptions specified in Regulatory Guide 1.4. Consistent with this Regulatory Guide, 100 percent of the noble gas inventory and 25 percent of the iodine inventory in the core are assumed to be immediately available for leakage from the primary containment.

However, all of this radioactivity is not released directly to the environment because there are a number of mitigating mechanisms which can delay or retain radioisotopes. The principal mechanism, the primary containment, substantially restricts the release rate of the radioisotopes. Following a postulated LOCA, another potential source of fission product release to the environment is the leakage of radioactive water from engineered safety feature equipment located outside containment. The fission products could then be released from the water into the atmosphere, resulting in offsite radiological consequences that contribute to the total dose from the LOCA.

The LOCA radiological consequence analysis for the LEU cores was performed assuming a ground-level release based on offeror-supplied plant-specific radioisotope release data. All possible leak paths (containment, bypass, and the emergency core cooling system) were included. Were a LOCA to occur, a substantial percentage of the releases would be expected to be elevated, which would be expected to reduce the consequences from those calculated in this analysis. To analyze the accident for a partial MOX core, the LEU isotopic activity was multiplied by the MOX/LEU ratios (from Table K–27) to provide a MOX core activity for each isotope. The LEU and MOX LOCA releases for Catawba and McGuire are provided in Table K–31 and for North Anna in Table K–32.

Table K–31. Catawba and McGuire LOCA Source Term

Isotope	LEU LOCA Release (Ci)	MOX/LEU Ratio	40% MOX Core Release (Ci)
Iodine 131	2.42×10^{4}	1.03	2.49×10^{4}
Iodine 132	7.76×10^{2}	1.02	7.92×10^{2}
Iodine 133	3.22×10^{3}	1.00	3.22×10^{3}
Iodine 134	6.55×10^{2}	0.98	6.42×10^{2}
Iodine 135	2.51×10^{3}	1.00	2.51×10^{3}
Krypton 83m	3.62×10^{3}	0.89	3.22×10^{3}
Krypton 85	1.96×10^{4}	0.78	1.53×10^{4}
Krypton 85m	1.96×10^{4}	0.86	1.68×10^{4}
Krypton 87	1.04×10^{4}	0.85	8.82×10^{3}
Krypton 88	3.23×10^{4}	0.84	2.72×10^{4}
Xenon 131m	2.79×10^{4}	1.02	2.84×10^{4}
Xenon 133	2.33×10^{6}	1.00	2.33×10^{6}
Xenon 133m	3.45×10^{4}	1.01	3.49×10^{4}
Xenon 135	2.90×10^{5}	1.28	3.71×10^{5}
Xenon 135m	1.40×10^{3}	1.04	1.46×10^{3}
Xenon 138	7.21×10^{3}	0.96	6.92×10^{3}

Key: LEU, low-enriched uranium; LOCA, loss-of-coolant accident.

Fuel-Handling Accident. The fuel-handling accident analysis was performed in a conservative manner, in accordance with Regulatory Guide 1.25 methodology (NRC 1972). In the fuel-handling accident scenario, a spent fuel assembly is dropped. The drop results in a breach of the fuel rod cladding, and a portion of the volatile fission gases from the damaged fuel rods is released. A fuel-handling accident would realistically result in only a fraction of the fuel rods being damaged. However, consistent with NRC methodology, all the fuel rods in the assembly are assumed to be damaged.

Table K–32. North Anna LOCA Source Term

Isotope	LEU LOCA Release (Ci)	MOX/LEU Ratio	40% MOX Core Release (Ci)
Iodine 131	3.68×10^{2}	1.03	3.79×10^{2}
Iodine 132	3.45×10^{2}	1.02	3.52×10^{2}
Iodine 133	5.87×10^{2}	1.00	5.87×10^{2}
Iodine 134	5.10×10^{2}	0.98	5.00×10^{2}
Iodine 135	5.01×10^{2}	1.00	5.01×10^{2}
Krypton 83m	4.26×10^{2}	0.89	3.79×10^{2}
Krypton 85	5.06×10^{1}	0.78	3.95×10^{1}
Krypton 85m	1.48×10^{3}	0.86	1.27×10^{3}
Krypton 87	2.22×10^{3}	0.85	1.89×10^{3}
Krypton 88	3.50×10^{3}	0.84	2.94×10^{3}
Xenon 131m	3.20×10^{1}	1.02	3.26×10^{1}
Xenon 133	6.91×10^{3}	1.00	6.91×10^{3}
Xenon 133m	1.70×10^{2}	1.01	1.72×10^{2}
Xenon 135	6.37×10^{3}	1.28	8.15×10^{3}
Xenon 135m	6.72×10^{2}	1.04	6.99×10^{2}
Xenon 138	1.90×10^{3}	0.96	1.82×10^{3}

Key: LEU, low-enriched uranium; LOCA, loss-of-coolant accident.

The accident is assumed to occur at the earliest time fuel-handling operations may begin after shutdown as identified in each plant's Technical Specifications.[8] The assumed accident time is 72 hr after shutdown at Catawba and McGuire. North Anna Technical Specifications require a minimum of 150 hr between shutdown and the initiation of fuel movement, but assumed an accident time of 100 hr.

As assumed in Regulatory Guide 1.25, the damaged assembly is the highest powered assembly being removed from the reactor. The values for individual fission product inventories in the damaged assembly are calculated assuming full power operation at the end of core life immediately preceding shutdown. All of the gap activity in the damaged rods is assumed to be released to the spent fuel pool. Noble gases released to the spent fuel pool are immediately released at ground level to the environment, but the water in the spent fuel pool greatly reduces the iodine available for release to the environment. It is assumed that all of the iodine escaping from the spent fuel pool is released to the environment at ground level over a 2-hr time period through the fuel-handling building ventilation system. The Catawba and McGuire UFSARs assume iodine filter efficiencies of 95 percent for both the inorganic and organic species. The North Anna UFSAR assumes a filter efficiency of 90 percent for the inorganic iodine and 70 percent for the organic iodine. The LEU and MOX source terms for Catawba and McGuire are provided in Table K–33 and the source terms for North Anna are provided in Table K–34.

The frequencies for the design basis LOCAs, obtained from the IPEs, are Catawba, 7.50×10^{-6}; McGuire, 1.50×10^{-5}; and North Anna, 2.10×10^{-5}. The frequencies of the fuel-handling accidents were estimated in lieu of plant-specific data. For conservatism, a frequency of 1×10^{-4} was chosen for the analysis.

[8] Technical Specifications are plant-specific operating conditions that control safety-related parameters of plant operation. Technical Specifications are part of the operating license and require an operating license amendment to change.

Table K–33. Catawba and McGuire Fuel-Handling Accident Source Term

Nuclide	LEU Release (Ci)	MOX/LEU Ratio	40% MOX Core Release
Iodine 131	3.83×10^{1}	1.03	3.94×10^{1}
Iodine 132	5.55×10^{1}	1.02	5.66×10^{1}
Iodine 133	8.00×10^{1}	1.00	8.00×10^{1}
Iodine 134	8.80×10^{1}	0.98	8.62×10^{1}
Iodine 135	7.55×10^{1}	1.00	7.55×10^{1}
Krypton 83m	9.47×10^{3}	0.89	8.43×10^{3}
Krypton 85	1.11×10^{3}	0.78	8.66×10^{2}
Krypton 85m	2.16×10^{4}	0.86	1.86×10^{4}
Krypton 87	4.04×10^{4}	0.85	3.43×10^{4}
Krypton 88	5.58×10^{4}	0.84	4.69×10^{4}
Xenon 133	1.60×10^{5}	1.00	1.60×10^{5}
Xenon 133m	4.81×10^{3}	1.01	4.86×10^{3}
Xenon 135	1.65×10^{5}	1.28	2.11×10^{5}
Xenon 135m	2.96×10^{4}	1.04	3.08×10^{4}
Xenon 138	1.34×10^{5}	0.96	1.29×10^{5}

Key: LEU, low-enriched uranium; LOCA, loss-of-coolant accident.

Table K–34. North Anna Fuel-Handling Accident Source Term

Nuclide	LEU Release (Ci)	MOX/LEU Ratio	40% MOX Core Release
Iodine 131	9.05×10^{1}	1.03	9.32×10^{1}
Iodine 132	1.37×10^{2}	1.02	1.40×10^{2}
Iodine 133	2.01×10^{2}	1.00	2.01×10^{2}
Iodine 134	2.36×10^{2}	0.98	2.31×10^{2}
Iodine 135	1.82×10^{2}	1.00	1.82×10^{2}
Krypton 85	2.60×10^{3}	0.78	2.03×10^{3}
Krypton 85m	2.65×10^{4}	0.86	2.28×10^{4}
Krypton 87	5.10×10^{4}	0.85	4.34×10^{4}
Krypton 88	7.25×10^{4}	0.84	6.09×10^{4}
Xenon 131m	4.56×10^{2}	1.02	4.65×10^{2}
Xenon 133	1.36×10^{5}	1.00	1.36×10^{5}
Xenon 133m	3.46×10^{3}	1.01	3.49×10^{3}
Xenon 135	3.70×10^{4}	1.28	4.74×10^{4}
Xenon 135m	3.74×10^{4}	1.04	3.89×10^{4}
Xenon 138	1.22×10^{5}	0.96	1.17×10^{5}

Key: LEU, low-enriched uranium; LOCA, loss-of-coolant accident.

K.7.2.5 Beyond-Design-Basis Events

Beyond-design-basis accidents (severe reactor accidents) are less likely to occur than reactor design basis accidents. In the reactor design basis accidents, the mitigating systems are assumed to be available. In the severe reactor accidents, even though the initiating event could be a design basis event (e.g., large-break LOCA), additional failures of mitigating systems would cause some degree of physical deterioration of the fuel in the reactor core and a possible breach of the containment structure leading to the direct release of radioactive materials to the environment.

The beyond-design-basis accident evaluation in the SPD EIS included a review of each plant's IPE. In 1988, the NRC required all licensees of operating plants to perform IPEs for severe accident vulnerabilities (Generic Letter 88-20) (NRC 1988), and indicated that a Probabalistic Risk Assessment (PRA) would be an acceptable approach to performing the IPE. A PRA evaluates, in full detail (quantitatively), the consequences of all potential events caused by the operating disturbances (known as internal initiating events) within each plant. The state-of-the-art PRA uses realistic criteria and assumptions in evaluating the accident progression and the systems required to mitigate each accident.

A plant-specific PRA for severe accident vulnerabilities starts with identification of initiating events (i.e., challenges to normal plant operation or accidents) that require successful mitigation to prevent core damage. These events are grouped into initiating event classes that have similar characteristics and require the same overall plant response.

Event trees are developed for each initiating event class. These event trees depict the possible sequence of events that could occur during the plant's response to each initiating event class. The trees delineate the possible combinations (sequences) of functional and/or system successes and failures that lead to either successful mitigation of the initiating event or core damage. Functional and/or system success criteria are developed based on the plant response to the class of accident sequences. Failure modes of systems that are functionally important to preventing core damage are modeled. This modeling process is usually done with fault trees that define the combinations of equipment failures, equipment outages, and human errors that could cause the failure of systems to perform the desired functions.

Quantification of the event trees leads to hundreds, or even thousands, of different end states representing various accident sequences that are either mitigated or lead to core damage. Each accident sequence and its associated end state has a unique "signature" because of the particular combination of system successes and failures. These end states are grouped together into plant damage states, each of which collects sequences for which the progression of core damage, the release of fission products from the fuel, the status of containment and its systems, and the potential for mitigating source terms are similar. The sum of all core damage accident sequences will then represent an estimate of plant core damage frequency. The analysis of core damage frequency calculations is called a Level 1 PRA, or front-end analysis.

Next, an analysis of accident progression, containment loading[9] resulting from the accident, and the structural response to the accident loading is performed. The primary objective of this analysis, which is called a Level 2 PRA, is to characterize the potential for, and magnitude of, a release of radioactive material from the reactor fuel to the environment, given the occurrence of an accident that damages the core. The analysis includes an assessment of containment performance in response to a series of severe accidents. Analysis of the progression of an accident (an accident sequence within a plant damage state) generates a time history of loads imposed on the containment pressure boundary. These loads would then be compared against the containment's structural performance limits. If the loads exceed the performance limits, the containment would be expected to fail; conversely, if the containment performance limits exceed the calculated loads, the containment would be expected to survive. Four modes of containment failure are defined: containment isolation failure, containment bypass, early containment failure, and late containment failure.

[9] Challenges to containment integrity such as elevated temperature or pressure are referred to as containment loading.

The magnitude of the radioactive release to the atmosphere in an accident is dependent on the timing of the reactor vessel failure and the containment failure. To determine the magnitude of the release, a containment event tree representing the time sequence of major phenomenological events that could occur during the formation and relocation of core debris (after core melt), availability of the containment heat removal system, and the expected mode of containment failures (i.e., bypass, early, and late), is developed. A reduced set of plant damage states is defined by culling the lower frequency plant damage states into higher frequency ones that have relatively similar severity and consequence potential. This condensed set is known as the key plant damage states. These key plant damage states would then become the initiating events for the containment event tree. The outcome of each sequence in this event tree represents a specific release category. Release categories that can be represented by similar source terms are grouped. Source terms associated with various release categories describe the fractional releases for representative radionuclide groups, as well as the timing, duration, and energy of release.

Beyond-design-basis accidents evaluated in the SPD EIS included only those scenarios that lead to containment bypass or failure because the public and environmental consequences would be significantly less for accident scenarios that do not lead to containment bypass or failure. The accidents evaluated consisted of a steam generator tube rupture, an early containment failure, a late containment failure, and an ISLOCA.

Steam Generator Tube Rupture. A beyond-design-basis steam generator tube rupture induced by high temperatures represents a containment bypass event. Analyses have indicated a potential for very high gas temperatures in the reactor coolant system during accidents involving core damage when the primary system is at high pressure. The high temperature could fail the steam generator tubes. As a result of the tube rupture, the secondary side may be exposed to full Reactor Coolant System pressures. These pressures are likely to cause relief valves to lift on the secondary side as they are designed to do. If these valves fail to close after venting, an open pathway from the reactor vessel to the environment can result.

Early Containment Failure. This accident is defined as the failure of containment prior to or very soon (within a few hours) after breach of the reactor vessel. A variety of mechanisms such as direct contact of core debris with the containment, rapid pressure and temperature loads, hydrogen combustion, and fuel-coolant interactions can cause structural failure of the containment. Early containment failure can be important because it tends to result in shorter warning times for initiating public protective measures, and because radionuclide releases would generally be more severe than if the containment fails late.

Late Containment Failure. A late containment failure involves structural failure of the containment several hours after breach of the reactor vessel. A variety of mechanisms such as gradual pressure and temperature increase, hydrogen combustion, and basemat melt-through by core debris can cause late containment failure.

ISLOCA. An ISLOCA refers to a class of accidents in which the reactor coolant system pressure boundary interfacing with a supporting system of lower design pressure is breached. If this occurs, the lower pressure system will be overpressurized and could rupture outside the containment. This failure would establish a flow path directly to the environment or, sometimes, to another building of small-pressure capacity.

For each of the proposed reactors, an assessment was made of the pre-accident inventories of each radioactive species in the reactor fuel, using information on the thermal power and refueling cycles. For the source term and offsite consequence analysis, the radioactive species were collected into groups that exhibit similar chemical behavior. The following groups represent the radionuclides considered to be most important to offsite consequences: noble gases, iodine, cesium, tellurium, strontium, ruthenium, lanthanum, cerium, and barium.

The LEU end-of-cycle isotopic activities (inventories) were multiplied by the MOX/LEU ratio to provide a MOX end-of-cycle activity for each isotope. The LEU and MOX core activities for Catawba and McGuire are provided in Table K–35. The activities for North Anna are provided in Table K–36.

Table K–35. Catawba and McGuire End-of-Cycle Core Activities

Isotope	LEU Core Activity (Ci)	MOX/ LEU Ratio	40% MOX Core Activity (Ci)	Isotope	LEU Core Activity (Ci)	MOX/ LEU Ratio	40% MOX Core Activity (Ci)
Americium 241	3.13×10^{3}	2.06	6.45×10^{3}	Niobium 95	1.41×10^{8}	0.94	1.33×10^{8}
Antimony 127	7.53×10^{6}	1.15	8.66×10^{6}	Plutonium 238	9.90×10^{4}	0.76	7.53×10^{4}
Antimony 129	2.67×10^{7}	1.07	2.85×10^{7}	Plutonium 239	2.23×10^{4}	2.06	4.60×10^{4}
Barium 139	1.70×10^{8}	0.97	1.65×10^{8}	Plutonium 240	2.82×10^{4}	2.20	6.20×10^{4}
Barium 140	1.68×10^{8}	0.98	1.65×10^{8}	Plutonium 241	4.74×10^{6}	1.79	8.49×10^{6}
Cerium 141	1.53×10^{8}	0.98	1.50×10^{8}	Praseodymium 143	1.46×10^{8}	0.95	1.39×10^{8}
Cerium 143	1.48×10^{8}	0.95	1.41×10^{8}	Rhodium 105	5.53×10^{7}	1.19	6.58×10^{7}
Cerium 144	9.20×10^{7}	0.91	8.37×10^{7}	Rubidium 86	5.10×10^{4}	0.77	3.93×10^{4}
Cesium 134	1.17×10^{7}	0.85	9.93×10^{6}	Ruthenium 103	1.23×10^{8}	1.11	1.36×10^{8}
Cesium 136	3.56×10^{6}	1.09	3.88×10^{6}	Ruthenium 105	7.98×10^{7}	1.18	9.42×10^{7}
Cesium 137	6.53×10^{6}	0.91	5.94×10^{6}	Ruthenium 106	2.79×10^{7}	1.28	3.57×10^{7}
Cobolt 58	8.71×10^{5}	0.86	7.49×10^{5}	Strontium 89	9.70×10^{7}	0.83	8.05×10^{7}
Cobolt 60	6.66×10^{5}	0.72	4.80×10^{5}	Strontium 90	5.24×10^{6}	0.75	3.93×10^{6}
Curium 242	1.20×10^{6}	1.43	1.71×10^{6}	Strontium 91	1.25×10^{8}	0.86	1.07×10^{8}
Curium 244	7.02×10^{4}	0.94	6.60×10^{4}	Strontium 92	1.30×10^{8}	0.89	1.16×10^{8}
Iodine 131	8.66×10^{7}	1.03	8.92×10^{7}	Technetium 99m	1.42×10^{8}	0.99	1.41×10^{8}
Iodine 132	1.28×10^{8}	1.02	1.30×10^{8}	Tellurium 127	7.28×10^{6}	1.16	8.44×10^{6}
Iodine 133	1.83×10^{8}	1.00	1.83×10^{8}	Tellurium 127m	9.63×10^{5}	1.20	1.16×10^{6}
Iodine 134	2.01×10^{8}	0.98	1.97×10^{8}	Tellurium 129	2.50×10^{7}	1.08	2.70×10^{7}
Iodine 135	1.73×10^{8}	1.00	1.73×10^{8}	Tellurium 129m	6.60×10^{6}	1.09	7.20×10^{6}
Krypton 85	6.69×10^{5}	0.78	5.22×10^{5}	Tellurium 131m	1.26×10^{7}	1.11	1.40×10^{7}
Krypton 85m	3.13×10^{7}	0.86	2.69×10^{7}	Tellurium 132	1.26×10^{8}	1.01	1.27×10^{8}
Krypton 87	5.72×10^{7}	0.85	4.87×10^{7}	Xenon 133	1.83×10^{8}	1.00	1.83×10^{8}
Krypton 88	7.74×10^{7}	0.84	6.50×10^{7}	Xenon 135	3.44×10^{7}	1.28	4.40×10^{7}
Lanthanum 140	1.72×10^{8}	0.97	1.67×10^{8}	Yttrium 90	5.62×10^{6}	0.76	4.27×10^{6}
Lanthanum 141	1.57×10^{8}	0.97	1.53×10^{8}	Yttrium 91	1.18×10^{8}	0.85	1.00×10^{8}
Lanthanum 142	1.52×10^{8}	0.97	1.47×10^{8}	Yttrium 92	1.30×10^{8}	0.89	1.16×10^{8}
Molybdenum 99	1.65×10^{8}	0.99	1.63×10^{8}	Yttrium 93	1.47×10^{8}	0.91	1.34×10^{8}
Neodymium 147	6.52×10^{7}	0.98	6.39×10^{7}	Zirconium 95	1.49×10^{8}	0.94	1.40×10^{8}
Neptunium 239	1.75×10^{9}	0.99	1.73×10^{9}	Zirconium 97	1.56×10^{8}	0.98	1.53×10^{8}

Key: LEU, low-enriched uranium.

Table K–36. North Anna End-of-Cycle Core Activities

Isotope	LEU Core Activity (Ci)	MOX/ LEU Ratio	40% MOX Core Activity (Ci)	Isotope	LEU Core Activity (Ci)	MOX/ LEU Ratio	40% MOX Core Activity (Ci)
Americium 241	1.03×10^{4}	2.06	2.13×10^{4}	Plutonium 238	1.99×10^{5}	0.76	1.51×10^{5}
Antimony 127	6.36×10^{6}	1.15	7.31×10^{6}	Plutonium 239	2.70×10^{4}	2.06	5.57×10^{4}
Antimony 129	2.41×10^{7}	1.07	2.58×10^{7}	Plutonium 240	3.43×10^{4}	2.20	7.54×10^{4}
Barium 139	1.39×10^{8}	0.97	1.35×10^{8}	Plutonium 241	9.82×10^{6}	1.79	1.76×10^{7}
Barium 140	1.37×10^{8}	0.98	1.34×10^{8}	Praseodymium 143	1.17×10^{8}	0.95	1.11×10^{8}
Cerium 141	1.25×10^{8}	0.98	1.22×10^{8}	Rhodium 105	7.22×10^{7}	1.19	8.59×10^{7}
Cerium 143	1.18×10^{8}	0.95	1.12×10^{8}	Rubidium 86	1.45×10^{4}	0.77	1.12×10^{4}
Cerium 144	9.70×10^{7}	0.91	8.82×10^{7}	Rubidium 103	1.16×10^{8}	1.11	1.28×10^{8}
Cesium 134	1.28×10^{7}	0.85	1.09×10^{7}	Rubidium 105	7.84×10^{7}	1.18	9.25×10^{7}
Cesium 136	3.42×10^{6}	1.09	3.72×10^{6}	Rubidium 106	3.83×10^{7}	1.28	4.90×10^{7}
Cesium 137	8.41×10^{6}	0.91	7.66×10^{6}	Strontium 89	7.48×10^{7}	0.83	6.21×10^{7}
Curium 242	2.72×10^{6}	1.43	3.88×10^{6}	Strontium 90	6.22×10^{6}	0.75	4.66×10^{6}
Curium 244	2.75×10^{5}	0.94	2.58×10^{5}	Strontium 91	9.36×10^{7}	0.86	8.05×10^{7}
Iodine 131	7.33×10^{7}	1.03	7.55×10^{7}	Strontium 92	1.04×10^{8}	0.89	9.23×10^{7}
Iodine 132	1.07×10^{8}	1.02	1.09×10^{8}	Technetium 99m	1.26×10^{8}	0.99	1.25×10^{8}
Iodine 133	1.52×10^{8}	1.00	1.52×10^{8}	Tellurium 127	6.21×10^{6}	1.16	7.21×10^{6}
Iodine 134	1.75×10^{8}	0.98	1.71×10^{8}	Tellurium 127m	9.87×10^{5}	1.20	1.18×10^{6}
Iodine 135	1.49×10^{8}	1.00	1.49×10^{8}	Tellurium 129	2.29×10^{7}	1.08	2.47×10^{7}
Krypton 85	3.51×10^{6}	0.78	2.74×10^{6}	Tellurium 129m	4.20×10^{6}	1.09	4.58×10^{6}
Krypton 85m	8.69×10^{5}	0.86	7.48×10^{5}	Tellurium 132	1.07×10^{8}	1.01	1.08×10^{8}
Krypton 87	3.86×10^{7}	0.85	3.28×10^{7}	Xenon 133	1.59×10^{8}	1.00	1.59×10^{8}
Krypton 88	5.46×10^{7}	0.84	4.59×10^{7}	Xenon 133m	4.69×10^{6}	1.01	4.73×10^{6}
Lanthanum 140	1.42×10^{8}	0.97	1.37×10^{8}	Xenon 135	4.47×10^{7}	1.28	5.72×10^{7}
Lanthanum 141	1.28×10^{8}	0.97	1.24×10^{8}	Yttrium 90	6.21×10^{6}	0.76	4.72×10^{6}
Lanthanum 142	1.24×10^{8}	0.97	1.21×10^{8}	Yttrium 91	9.93×10^{7}	0.85	8.44×10^{7}
Molybdenum 99	1.43×10^{8}	0.99	1.42×10^{8}	Yttrium 92	1.01×10^{8}	0.89	8.97×10^{7}
Neodymium 147	5.12×10^{7}	0.98	5.02×10^{7}	Yttrium 93	1.16×10^{8}	0.91	1.05×10^{8}
Neptunium 239	1.51×10^{9}	0.99	1.50×109	Zirconium 95	1.27×10^{8}	0.94	1.20×10^{8}
Niobium 95	1.31×10^{8}	0.94	1.23×10^{8}	Zirconium 97	1.28×10^{8}	0.98	1.26×10^{8}

Key: LEU, low-enriched uranium.

The source term for each accident, taken from each plant's PRA, is described by the release height, timing, duration, and heat content of the plume, the fraction of each isotope group released, and the warning time (time when offsite officials are warned that an emergency response should be initiated). The PRAs included several release categories for each bypass and failure scenario. These release categories were screened for each accident scenario to determine which release category resulted in the highest risk. The risk was determined by multiplying the consequences by the frequency for each release category. The release category with the highest risk for each scenario was used in the SPD EIS analysis. The highest risk release category source terms for Catawba, McGuire, and North Anna are presented in Table K–37. Also included in each release category characterization is the frequency of occurrence.

The overall risk from beyond-design-basis accidents can be described by the sum of risks from all beyond-design-basis accidents. The group of accidents derived from the screening process results in the highest risks from the containment bypass and failure scenarios. The screened-out accidents in these categories not only

Table K–37. Beyond-Design-Basis Accident Source Terms

Accident	Parameters	Release Category	Frequency	Release Fractions								
				Xe/Kr	**I**	**Cs/Rb**	**Te/Sb**	**Sr**	**Ru/Mo**	**La**	**Ce**	**Ba**
				CATAWBA								
SG tube rupture[a]	Time: 20 hr Duration: 1.0 hr Energy: 1.0×10^{4} cal/sec (4.2×10^{4} W) Elevation: 10.0 m Warning time: 7.5 hr	1.04	6.31×10^{-10}	1.0	7.7×10^{-1}	7.9×10^{-1}	7.3×10^{-1}	5.0×10^{-3}	9.4×10^{-2}	1.3×10^{-4}	NA	4.0×10^{-2}
Early containment failure	Time: 6.0 hr Duration: 0.5 hr Energy: 2.0×10^{7} cal/sec (8.37×10^{7} W) Elevation: 10.0 m Warning time: 5.5 hr	5.01	3.42×10^{-8}	1.0	5.5×10^{-2}	4.8×10^{-2}	3.0×10^{-2}	2.5×10^{-4}	2.2×10^{-3}	1.2×10^{-4}	NA	1.7×10^{-3}
Late containment failure	Time: 18.5 hr Duration: 0.5 hr Energy: 1.0×10^{7} cal/sec (4.2×10^{7} W) Elevation: 10.0 m Warning time: 18.0 hr	6.01	1.21×10^{-5}	1.0	3.6×10^{-3}	3.9×10^{-3}	1.8×10^{-3}	5.2×10^{-5}	3.8×10^{-4}	2.6×10^{-5}	NA	1.6×10^{-4}
Interfacing systems LOCA	Time: 6.0 hr Duration: 1.0 hr Energy: 1.0×10^{4} cal/sec (4.2×10^{4} W) Elevation: 10.0 m Warning time: 5.5 hr	2.04	6.9×10^{-8}	1.0	8.2×10^{-1}	8.2×10^{-1}	7.9×10^{-1}	5.8×10^{-2}	2.1×10^{-1}	3.1×10^{-2}	NA	1.4×10^{-1}

Table K–37. Beyond-Design-Basis Accident Source Terms (Continued)

Accident	Parameters	Release Category	Frequency	Release Fractions								
				Xe/Kr	I	Cs/Rb	Te/Sb	Sr	Ru/Mo	La	Ce	Ba
McGUIRE												
SG tube rupture	Time: 20.0 hr Duration: 1.0 hr Energy: 1.0×10^{4} cal/sec (4.2×10^{4} W) Elevation: 10.0 m Warning time: 7.5 hr	1.04	5.81×10^{-9}	1.0	7.7×10^{-1}	7.9×10^{-1}	7.3×10^{-1}	5.0×10^{-3}	9.4×10^{-2}	1.3×10^{-4}	NA	4.0×10^{-2}
Early containment failure	Time: 6.0 hr Duration: 0.5 hr Energy: 2.0×10^{7} cal/sec (8.37×10^{7} W) Elevation: 10.0 m Warning time: 5.5 hr	5.01	9.89×10^{-8}	1.0	4.4×10^{-2}	3.5×10^{-2}	2.1×10^{-2}	1.4×10^{-4}	4.3×10^{-3}	2.0×10^{-5}	NA	1.4×10^{-3}
Late containment failure	Time: 32.0 hr Duration: 0.5 hr Energy: 1.0×10^{7} cal/sec (4.2×10^{7} W) Elevation: 10.0 m Warning time: 31.5 hr	6.01	7.21×10^{-6}	1.0	3.2×10^{-3}	2.4×10^{-3}	3.3×10^{-3}	1.0×10^{-8}	5.8×10^{-8}	1.0×10^{-9}	NA	1.8×10^{-7}
Interfacing systems LOCA	Time: 3.0 hr Duration: 1.0 hr Energy: 1.0×10^{4} cal/sec (4.2×10^{4} W) Elevation: 10.0 m Warning time: 2.0 hr	2.04	6.35×10^{-7}	1.0	7.5×10^{-1}	7.5×10^{-1}	6.6×10^{-1}	4.2×10^{-2}	1.5×10^{-1}	2.0×10^{-2}	NA	9.8×10^{-2}

Table K–37. Beyond-Design-Basis Accident Source Terms (Continued)

Accident	Parameters	Release Category	Frequency	Release Fractions								
				Xe/Kr	I	Cs/Rb	Te/Sb	Sr	Ru/Mo	La	Ce	Ba
				NORTH ANNA								
SG tube rupture	Time: 20.3 hr Duration: 1.0 hr Energy: 8.48×10^{3} cal/sec (3.55×10^{4} W) Elevation: 10.0 m Warning time: 7.8 hr	24	7.38×10^{-6}	9.96×10^{-1}	5.2×10^{-1}	5.4×10^{-1}	2.6×10^{-3}/ 6.8×10^{-1}	3.4×10^{-2}	1.4×10^{-1}	5.5×10^{-5}	5.2×10^{-3}	2.1×10^{-2}
Early containment failure	Time: 3.056 hr Duration: 0.5 hr Energy: 1.696×10^{7} cal/sec (7.1×10^{7} W) Elevation: 10.0 m Warning time: 2.556 hr	7	1.60×10^{-7}	9.0×10^{-1}	7.4×10^{-2}	9.7×10^{-2}	1.4×10^{-2}/ 1.3×10^{-1}	1.5×10^{-2}	2.5×10^{-2}	8.1×10^{-6}	9.7×10^{-5}	8.7×10^{-3}
Late containment failure	Time: 8.33 hr Duration: 0.5 hr Energy: 8.48×10^{6} cal/sec (3.55×10^{7} W) Elevation: 10.0 m Warning time: 7.83 hr	9	2.46×10^{-6}	8.2×10^{-1}	2.3×10^{-6}	1.4×10^{-5}	1.6×10^{-5}/ 1.2×10^{-4}	3.2×10^{-4}	3.9×10^{-4}	1.8×10^{-11}	1.4×10^{-11}	1.3×10^{-5}
Interfacing systems LOCA[b]	Time: 5.56 hr Duration: 1.0 hr Energy: 8.48×10^{3} cal/sec (3.55×10^{4} W) Elevation: 10.0 m Warning time: 4.56 hr	23	2.40×10^{-7}	9.4×10^{-1}	2.9×10^{-1}	3.1×10^{-1}	1.6×10^{-5}/ 5.0×10^{-1}	2.3×10^{-1}	2.8×10^{-1}	3.6×10^{-4}	3.7×10^{-2}	1.5×10^{-1}

[a] McGuire data was used for the Catawba steam generator tube rupture event to compare similar scenarios.

[b] McGuire release duration, elevation, and warning time span were used for North Anna in lieu of plant-specific information.

Key: LOCA, loss-of-coolant accident; NA, not applicable; SG, steam generator.

result in lower consequences, but also have much lower probabilities, often resulting in risks several orders of magnitude lower. The other type of severe accident scenario for these reactors results in an intact containment. The risks from these events are several orders of magnitude lower than the risks from the bypass and failure scenarios. Therefore, a summation of the severe accident risks presented in the SPD EIS is a good indicator of overall risk.

Evacuation Information. This analysis conservatively assumes that 95 percent of the population within the 16-km (10-mi) emergency planning zone participated in an evacuation. It was also assumed that the five percent of the population that did not participate in the initial evacuation was relocated within 12 to 24 hr after plume passage, based on the measured concentrations of radioactivity in the surrounding area and the comparison of projected doses with Environmental Protection Agency (EPA) guidelines. Longer term countermeasures (e.g., crop or land interdiction) were based on EPA Protective Action Guides.

Each beyond-design-basis accident scenario has a warning time and a subsequent release time. The warning time is the time at which notification is given to offsite emergency response officials to initiate protective measures for the surrounding population. The release time is the time when the release to the environment begins. The minimum time between the warning time and the release time is one-half hour. The minimum time of one-half hour is enough time to evacuate onsite personnel (i.e., noninvolved workers). This also conservatively assumes that an onsite emergency has not been declared prior to initiating an offsite notification. Intact containment severe accident scenarios, which were not analyzed because of their insignificant offsite consequences, take place on an even longer time frame.

K.7.2.6 Accident Impacts

Accident impacts are presented in terms of increased risk. Increased risk is defined as the additional risk resulting from using a partial MOX core rather than an LEU core. For example, if the risk of an LCF from an accident with an LEU core is 1.0×10^{-6} and the risk of an LCF from the same accident with a MOX core is 1.1×10^{-6}, then the increased risk of an LCF is 1.0×10^{-7} ($1.1\times10^{-6} - 1.0\times10^{-6} = 1.0\times10^{-7}$).

Tables K–38 through K–43 present the consequences and risks of the postulated set of accidents at Catawba, McGuire, and North Anna, respectively. The receptors include a noninvolved worker located 640 m (0.4 mi) from the release point, the MEI, and the population within an 80-km (50-mi) radius of the reactor site. The consequences and risks are presented for both the current LEU-only and the proposed 40 percent MOX core configurations.

Table K–44 shows the ratios of accident impacts with the proposed 40 percent MOX core to the impacts with the current LEU core. This table shows that the increased risk from accidents to the surrounding population from a MOX core is, on average, less than 5 percent. For the fuel-handling accident at all three plants, the risk is reduced when using MOX fuel.

Severe accident scenarios that postulate large abrupt releases could result in prompt fatalities if the radiation dose is sufficiently high. Of the accidents analyzed in the SPD EIS, the ISLOCA and steam generator tube rupture at Catawba and McGuire, and the ISLOCA at North Anna were the only accidents that resulted in doses high enough to cause prompt fatalities. However, the number of prompt fatalities is expected to increase only for the ISLOCA scenarios. Table K–45 shows the estimated number of prompt fatalities estimated to result from these accidents.

Table K–38. Design Basis Accident Impacts for Catawba With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
Loss-of-coolant accident	7.50×10^{-6}	LEU	3.78	1.51×10^{-3}	1.81×10^{-7}	1.44	7.20×10^{-4}	8.64×10^{-8}	3.64×10^{3}	1.82	2.19×10^{-4}
		MOX	3.85	1.54×10^{-3}	1.86×10^{-7}	1.48	7.40×10^{-4}	8.88×10^{-8}	3.75×10^{3}	1.88	2.26×10^{-4}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.275	1.10×10^{-4}	1.78×10^{-7}	0.138	6.90×10^{-5}	1.10×10^{-7}	1.12×10^{2}	5.61×10^{-2}	8.98×10^{-5}
		MOX	0.262	1.05×10^{-4}	1.68×10^{-7}	0.131	6.55×10^{-5}	1.05×10^{-7}	1.10×10^{2}	5.48×10^{-2}	8.77×10^{-5}

[a] Likelihood (or probability) of cancer fatality for a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary—given exposure (762 m [2,500 ft]) to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of a cancer fatality over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

Table K–39. Beyond-Design-Basis Accident Impacts for Catawba With LEU and MOX Fuels

			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
SG tube rupture[e]	6.31×10^{-10}	LEU	3.46×10^{2}	0.346	3.49×10^{-9}	5.71×10^{6}	5.20×10^{3}	5.25×10^{-5}
		MOX	3.67×10^{2}	0.367	3.71×10^{-9}	5.93×10^{6}	5.42×10^{3}	5.47×10^{-5}
Early containment failure	3.42×10^{-8}	LEU	5.97	2.99×10^{-3}	1.63×10^{-9}	7.70×10^{5}	4.62×10^{2}	2.53×10^{-4}
		MOX	6.01	3.01×10^{-3}	1.65×10^{-9}	8.07×10^{5}	4.84×10^{2}	2.66×10^{-4}
Late containment failure	1.21×10^{-5}	LEU	3.25	1.63×10^{-3}	3.15×10^{-7}	3.93×10^{5}	1.97×10^{2}	3.81×10^{-2}
		MOX	3.48	1.74×10^{-3}	3.38×10^{-7}	3.78×10^{5}	1.90×10^{2}	3.68×10^{-2}
ISLOCA	6.90×10^{-8}	LEU	1.40×10^{4}	1	1.10×10^{-6}	2.64×10^{7}	1.56×10^{4}	1.73×10^{-2}
		MOX	1.60×10^{4}	1	1.10×10^{-6}	2.96×10^{7}	1.69×10^{4}	1.87×10^{-2}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatality over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire timing and release fractions were used to compare like scenarios.

Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

Table K–40. Design Basis Accident Impacts for McGuire With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundaries			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
Loss-of-coolant accident	1.50×10^{-5}	LEU	5.31	2.12×10^{-3}	5.10×10^{-7}	2.28	1.14×10^{-3}	2.74×10^{-7}	3.37×10^{3}	1.69	4.06×10^{-4}
		MOX	5.46	2.18×10^{-3}	5.25×10^{-7}	2.34	1.17×10^{-3}	2.82×10^{-7}	3.47×10^{3}	1.74	4.18×10^{-4}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.392	1.57×10^{-4}	2.51×10^{-7}	0.212	1.06×10^{-4}	1.70×10^{-7}	99.1	4.96×10^{-2}	7.94×10^{-5}
		MOX	0.373	1.49×10^{-4}	2.38×10^{-7}	0.201	1.01×10^{-4}	1.62×10^{-7}	97.3	4.87×10^{-2}	7.79×10^{-5}

[a] Likelihood (or probability) of cancer fatality for a hypothetical individual–a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of a cancer fatality over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

Table K–41. Beyond-Design-Basis Accident Impacts for McGuire With LEU and MOX Fuels

			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
SG tube rupture[e]	5.81×10^{-9}	LEU	6.10×10^{2}	0.610	5.66×10^{-8}	5.08×10^{6}	4.65×10^{3}	4.32×10^{-4}
		MOX	6.47×10^{2}	0.647	6.02×10^{-8}	5.28×10^{6}	4.85×10^{3}	4.51×10^{-4}
Early containment failure	9.89×10^{-8}	LEU	12.2	6.10×10^{-3}	9.65×10^{-9}	7.90×10^{5}	4.57×10^{2}	7.23×10^{-4}
		MOX	12.6	6.30×10^{-3}	9.97×10^{-9}	8.04×10^{5}	4.67×10^{2}	7.39×10^{-4}
Late containment failure	7.21×10^{-6}	LEU	2.18	1.09×10^{-3}	1.26×10^{-7}	3.04×10^{5}	1.52×10^{2}	1.76×10^{-2}
		MOX	2.21	1.11×10^{-3}	1.28×10^{-7}	2.96×10^{5}	1.48×10^{2}	1.71×10^{-2}
ISLOCA	6.35×10^{-7}	LEU	1.95×10^{4}	1	1.02×10^{-5}	1.79×10^{7}	1.19×10^{4}	0.121
		MOX	2.19×10^{4}	1	1.02×10^{-5}	1.97×10^{7}	1.27×10^{4}	0.129

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire timing and release fractions were used to compare like scenarios.
Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

Table K–42. Design Basis Accident Impacts for North Anna With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	Frequency (per year)	LEU or MOX Core	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (person-rem)	Latent Cancer Fatalities[c]	Risk of Latent Cancer Fatalities (over campaign)[d]
Loss-of-coolant accident	2.10×10^{-5}	LEU	0.114	4.56×10^{-5}	1.53×10^{-8}	3.18×10^{-2}	1.59×10^{-5}	5.34×10^{-9}	39.4	1.97×10^{-2}	6.62×10^{-6}
		MOX	0.115	4.60×10^{-5}	1.55×10^{-8}	3.20×10^{-2}	1.60×10^{-5}	5.38×10^{-9}	40.3	2.02×10^{-2}	6.78×10^{-6}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.261	1.04×10^{-4}	1.66×10^{-7}	9.54×10^{-2}	4.77×10^{-5}	7.63×10^{-8}	29.4	1.47×10^{-2}	2.35×10^{-5}
		MOX	0.239	9.56×10-5	1.53×10^{-7}	8.61×10^{-2}	4.31×10^{-5}	6.90×10^{-8}	27.5	1.38×10^{-2}	2.21×10^{-5}

[a] Likelihood (or probability) of cancer fatality for a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft])—given exposure to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of a cancer fatality over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

Table K–43. Beyond-Design-Basis Accident Impacts for North Anna With LEU and MOX Fuels

			Impacts on Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
SG tube rupture[e]	7.38×10^{-6}	LEU	2.09×10^{2}	0.209	2.46×10^{-5}	1.73×10^{6}	1.22×10^{3}	0.144
		MOX	2.43×10^{2}	0.243	2.86×10^{-5}	1.84×10^{6}	1.33×10^{3}	0.157
Early containment failure[e]	1.60×10^{-7}	LEU	19.6	1.96×10^{-2}	5.02×10^{-8}	8.33×10^{5}	4.52×10^{2}	1.16×10^{-3}
		MOX	21.6	2.16×10^{-2}	5.54×10^{-8}	8.42×10^{5}	4.61×10^{2}	1.18×10^{-3}
Late containment failure[e]	2.46×10^{-6}	LEU	1.12	5.60×10^{-4}	2.21×10^{-8}	4.04×10^{4}	20.2	7.95×10^{-4}
		MOX	1.15	5.75×10^{-4}	2.26×10^{-8}	4.43×10^{4}	22.1	8.70×10^{-4}
ISLOCA[e]	2.40×10^{-7}	LEU	1.00×10^{4}	1	3.84×10^{-6}	4.68×10^{6}	2.98×10^{3}	1.14×10^{-2}
		MOX	1.22×10^{4}	1	3.84×10^{-6}	5.41×10^{6}	3.39×10^{3}	1.30×10^{-2}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire release durations and warning times were used in lieu of site specific data.
Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

Table K–44. Ratio of Accident Impacts for MOX-Fueled and LEU-Fueled Reactors (MOX Impacts/Uranium Impacts)

	Catawba			McGuire			North Anna		
Accident	**Worker**	**MEI**	**Population**	**Worker**	**MEI**	**Population**	**Worker**	**MEI**	**Population**
LOCA	1.019	1.028	1.033	1.028	1.026	1.030	1.009	1.006	1.025
FHA	0.953	0.949	0.977	0.952	0.948	0.982	0.916	0.903	0.939
SGTR	NA	1.061	1.042	NA	1.061	1.043	NA	1.163	1.090
Early	NA	1.007	1.048	NA	1.033	1.022	NA	1.102	1.020
Late	NA	1.071	0.964	NA	1.014	0.974	NA	1.027	1.094
ISLOCA	NA	1.143	1.083	NA	1.123	1.067	NA	1.220	1.138

Key: Early, early containment; FHA, fuel-handling accident; ISLOCA, interfacing systems loss-of-coolant accident; Late, late containment; LEU, low-enriched uranium; LOCA, loss-of-coolant accident; MEI, maximally exposed individual; NA, not applicable; SGTR, steam generator tube rupture.

K.7.2.6.1 Catawba

Design Basis Accidents. Table K–38 shows the risks and consequences associated with a LOCA and spent-fuel-handling accident at Catawba. The greatest risk increase to the surrounding population for a design basis accident with a MOX core configuration is approximately 3.3 percent from the LOCA. If this accident were to occur, the consequences in terms of LCFs in the surrounding population within 80 km (50 mi) would be 1.82 LCFs for an LEU core and 1.88 LCFs for a partial MOX core. The increased risk, in terms of an LCF, to the noninvolved worker is 1 in 200 million (5.0×10^{-9}) per 16-year campaign; the MEI, one 1 in 420 million (2.4×10^{-9}) per 16-year campaign; and the population, 1 in 140,000 (7.0×10^{-6}) per 16-year campaign.

Table K–45. Prompt Fatalities for MOX-Fueled and LEU-Fueled Reactors

Accident Scenario	LEU	MOX
Steam generator tube rupture		
Catawba	1	1
McGuire	1	1
North Anna	0	0
Interfacing systems loss-of-coolant accident		
Catawba	815	843
McGuire	398	421
North Anna	54	60

Key: LEU, low-enriched uranium.

Beyond-Design-Basis Accidents. Table K–39 shows the risks and consequences associated with four beyond-design-basis accidents at Catawba. Table K–45 shows prompt fatalities. The greatest risk increase to the surrounding population from a beyond-design-basis accident with a MOX core configuration is approximately 8.3 percent from the ISLOCA. If this accident were to occur, the consequences in terms of LCFs and prompt fatalities in the surrounding population within 80 km (50 mi) would be approximately 16,400 fatalities for an LEU core and 17,700 fatalities for a partial MOX core. The increased risk, in terms of an LCF, to the population is 1 in 710 (1.4×10^{-3}) per 16-year campaign. The increased risk of a prompt fatality is 1 in 32,000 (3.1×10^{-5}) per 16-year campaign.

K.7.2.6.2 McGuire

Design Basis Accidents. Table K–40 shows the risks and consequences associated with a LOCA and spent-fuel-handling accident at McGuire. The greatest risk increase to the surrounding population for a design basis accident with a MOX core configuration is 3.0 percent from the LOCA. If this accident were to occur, the consequences in terms of LCFs in the surrounding population within 80 km (50 mi) would be 1.69 LCFs for an LEU core and 1.74 LCFs for a partial MOX core. The increased risk, in terms of an LCF, to the noninvolved worker is 1 in 67 million (1.5×10^{-8}) per 16-year campaign; the MEI, 1 in 120 million (8.0×10^{-9}) per 16-year campaign; and the population, 1 in 83,000 (1.2×10^{-5}) per 16-year campaign.

Beyond-Design-Basis Accidents. Table K–41 shows the risks and consequences associated with four beyond-design-basis accidents at McGuire. Table K–45 shows prompt fatalities. The greatest risk increase to the surrounding population for a beyond-design-basis accident with a MOX core configuration is approximately 6.6 percent from the ISLOCA. If this accident were to occur, the consequences in terms of LCFs and prompt fatalities in the surrounding population within 80 km (50 mi) would be approximately 12,300 fatalities with an LEU core and 13,100 with a partial MOX core. The increased risk of an LCF to the population is 1 in 120 (8.0×10^{-3}) per 16-year campaign. The increased risk of a prompt fatality is 1 in 4,300 (2.3×10^{-4}) per 16-year campaign.

K.7.2.6.3 North Anna

Design Basis Accidents. Table K–42 shows the risks and consequences associated with a LOCA and spent-fuel-handling accident at North Anna. The greatest risk increase to the surrounding population for a design-basis-accident with a MOX core configuration is approximately 2.5 percent from the LOCA. If this accident were to occur, the consequences in terms of LCFs in the surrounding population within 80 km (50 mi) would be 1.97×10^{-2} LCF for an LEU core and 2.02×10^{-2} LCF for a partial MOX core. The increased risk, in terms of an LCF, to the noninvolved worker is 1 in 5.0 billion (2.0×10^{-10}) per 16-year campaign; the MEI, 1 in 25 billion (4.0×10^{-11}) per 16-year campaign; and the population, 1 in 6.2 million (1.6×10^{-7}) per 16-year campaign.

Beyond-Design-Basis Accidents. Table K–43 shows the risks and consequences associated with four beyond-design-basis accidents at North Anna. Table K–45 shows prompt fatalities. The greatest risk increase to the surrounding population from a beyond-design-basis accident with a MOX core configuration is approximately 14 percent from the ISLOCA. If this accident were to occur, the consequences in terms of LCFs and prompt fatalities in the surrounding populations within 80 km (50 mi) would be approximately 3,000 fatalities for an LEU core and 3,450 fatalities for a partial MOX core. The increased risk of an LCF to the population is 1 in 620 (1.6×10^{-3}) per 16-year campaign. The increased risk of a prompt fatality is 1 in 43,000 (2.3×10^{-5}) per 16-year campaign.

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